Response to referee comments and suggestions on bg-2018-521 by N. Löbs et al.: "Microclimatic and ecophysiological conditions experienced by epiphytic bryophytes in an Amazonian rain forest"

Manuscript format description:
Black text shows the original referee comment, and blue text shows the response of the authors and the explicit change in the text. The figure and table numbers refer to the revised manuscript.

Anonymous Referee #2 submitted the comments RC2

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General referee comment:

The authors provide a description of bryophyte occurrence and microclimate in a tropical forest canopy. These data are scarce and therefore crucial for a variety of applications that the authors list at various times in the manuscript.

General author response: We would like to thank reviewer 2 for his/her appreciation of the microclimate data and the productive comments, which helped us to substantially improve our manuscript.

Referee comment 1:

First, amongst these are poor organization and a general lack of coherence. Facts about bryophytes (such as they are poikilohydric) are repeated often. No clear hypotheses or research questions are outlined. The introduction tells us that bryophytes are 'cool' and important to study but doesn't do a good job of setting up the study itself. Until the end of the methods section, I didn't realize that gas exchange measurements were not performed (something that is mentioned in abstract- If gas exchange in epiphytes is essential, why did the authors not make these measurements?).

Author comment 1:

In the introduction, our aim was to introduce the ecosystem and study site, the invested organisms and communities, and also the measurement approach. As this aim seems to be only partly fulfilled, we thoroughly checked and restructured the introduction. Specific changes were made to bring more clarity into the abstract and the methods section to facilitate an understanding of the study. CO_2 gas exchange measurements indeed would be interesting here, but go beyond the scope of the current study. They represent a major study by themselves, which should be conducted in the near future. For now, we used reliable literature data to investigate to activity patterns of bryophytes when respiration and photosynthesis potentially take place.

Author changes in the text 1:

P2 L7: “In this study, we present data on the microclimatic conditions, including water content, temperature, and light intensities experienced by epiphytic bryophytes along a vertical gradient and combine these with “above-canopy climate” data collected at the *Amazon Tall Tower Observatory* (*ATTO*) in the Amazonian rain forest between October 2014 and December 2016.”

P2 L20: “For further investigations of the physiological activity patterns, CO_2 gas exchange measurements would be extremely helpful to characterize the response of key organisms to the environmental conditions and parameters.”

Referee comment 2:

While I am quite satisfied by the measurement protocols and methodology (and that the epiphyte wetness-drying data are novel and important) the study ends up being merely a data reporting exercise with conclusions that often seem unsubstantiated by the data that are presented. Other times conclusions are trivial. For instance, Pg 18, lines 18-23 it is suggested that it is dark in the understory and therefore photosynthesis is light limited. I do not think that today one needs to go to the Amazon to make this conclusion, as this has been known for decades (for e.g. read classic reviews by Chazdon and Fetcher, 1984; Mooney et al., 1984). I seem facetious here, but the authors could use the same data to build upon these earlier findings, and find some nuance and/or insights. What is the knowledge gap that you are trying to fill with your measurements?

Author comment 2:

The main results and conclusions were revised by us to present the data in a more logical and substantiated way. We also utilized the literature offered by you, as it helped to arrange our results in a better framework. In our opinion, one major advantage of our study is, that we performed long-term measurements (running continuously over more than two years) at several heights along a trunk, thus obtaining a vertical profile of the conditions within the vegetation. We now highlight this aspect, apart from other some other, and with this new structure, we think we can emphasize and improve its significance.

Author changes in the text 2:

P3 L23: “*Studies in temperate zones address the importance of cryptogamic communities for this ecosystem (Gimeno et al., 2017; Rastogi et al., 2018). In contrast to that, there are only few data available for tropical regions. There is a gap of information regarding the functioning of those organisms in an environment with an almost constantly high relative humidity and temperature values. Thus, with these long-term continuous measurements we aim to provide data on seasonality patterns and also vertical gradients of microclimatic conditions within the canopy.*

In the current study, we present the microclimatic conditions, including temperature, light, and water content of epiphytic bryophyte communities and an estimation of their activity patterns in response to annual and seasonal variations of climatic conditions, as well as along a vertical gradient from the understory to the canopy of the forest.”

Referee comment 3:

I want to be clear that I do not think that this work is unpublishable, rather a considerable amount of work needs to be done, especially in the writing, to ensure that it is. The advantage of the study is that the authors have collected a vast amount of important data, and there are several questions that can be formulated and answered. For instance, Fig S.5 is very interesting, and one could speculate about the significance of Tair -TCryptogram relationship in different parts of the canopy, and its significance to physiology. Another question could be the importance of light flecks, since you have carefully measured PPFD within the canopy. Fog is also measured but these data seem largely ignored (I wonder if you had leaf wetness sensors, those data could bolster the study tremendously). I would recommend the corresponding author to read some of the classic literature on epiphyte distribution and abundance (e.g. Benzing, 1984). With some more data exploration and thought I think this could be a very significant contribution. In its current form however, the manuscript reads like an early draft of a thesis or a dissertation chapter, and I do not see it fit for publication in Biogeosciences, or a journal of similar repute.

Author comment 3:

We appreciate this criticism and now put more effort into the analysis and interpretation of the long-term data collected by us.

The relevance of fog was investigated in more detail and its relevance for the WC of the bryophytes is illustrated in the text and in Fig. S8 below. We also analyzed light flecks in the updated version. Unfortunately, no leaf wetness sensors have been installed, so this kind of data cannot be used.

Author change in the text 3:

P12 L16: "Furthermore, fog might serve as an additional water source for the epiphytic bryophytes, as the WC of the bryophytes increases upon fog events (Fig. S8)."

P19 L3:" *In the understory, the WC of cryptogams seems to be predominantly regulated by rain events and the vegetation reduces the evaporation by its shadowing effect. An increased RH mostly slows down the drying in the understory, whereas in the canopy a nightly increase of RH also causes an increase of the bryophyte WC (Fig. 2). The effect of fog events is hard to distinguish from the influence of high RH, as fog occurs when high RH persists. However, some events indicate an increase of the bryophyte WC upon fog (Fig. S8).*

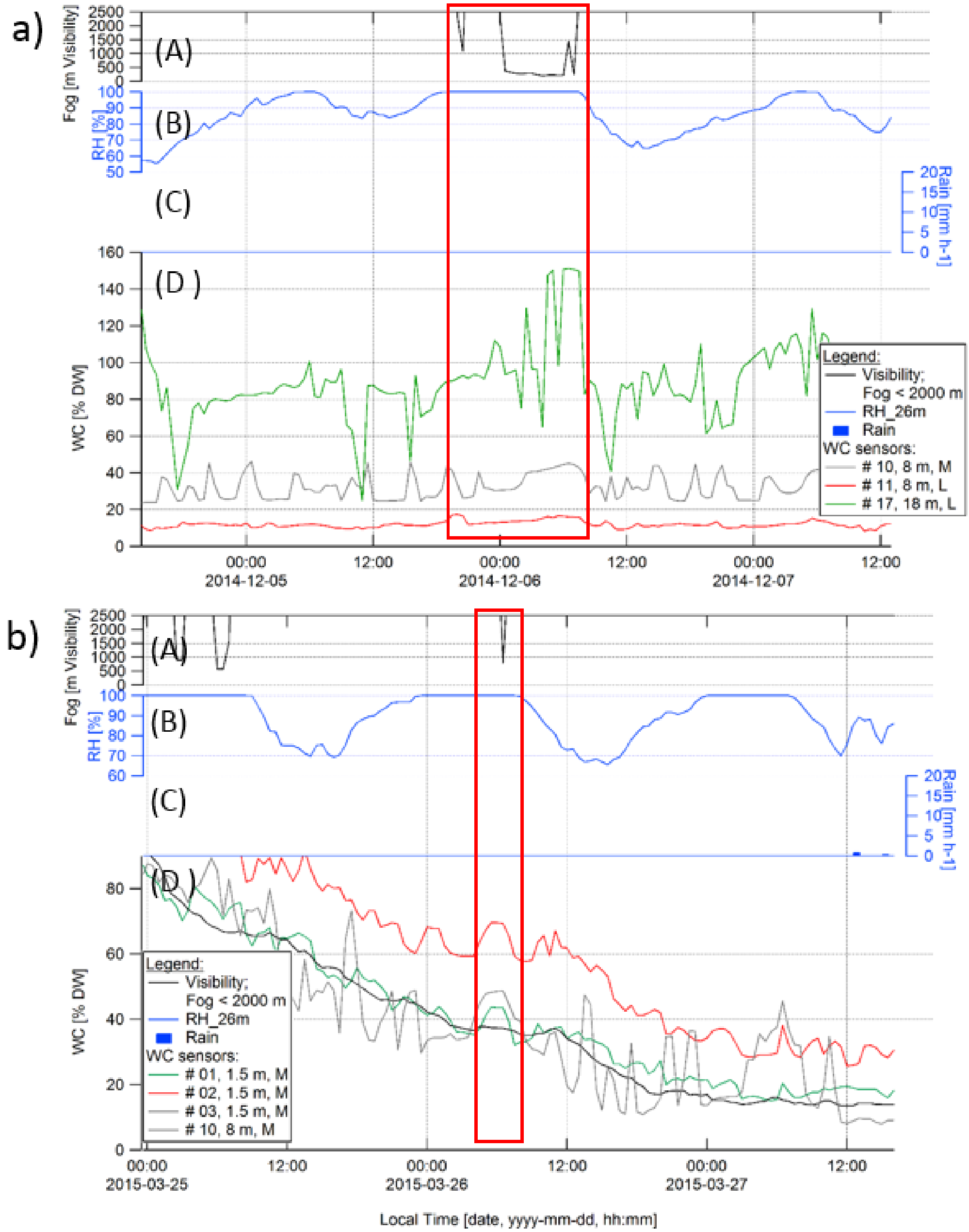

Figure S8: Two exemplary fog events and the reaction of the moisture sensors of the bryophytes (a and b). Each panel presents (A) a fog event defined by a visibility < 2000 m, (B) relative air humidity (RH), (C) rain, and (D) the water content (WC) of the bryophytes. In each panel, the fog event of interest is marked by a red box. For the WC sensors the number, height of installation, and division (M = Moss, L = Liverwort) are given.

Referee comment 4:

Finally, authors should provide data access via a link with a doi to a data repository. I wonder if this is required of papers that are submitted to Biogeosciences.

Author comment 4:

The database on the water content, temperature, and light conditions of epiphytes is uploaded to the ATTO data portal (www.attoproject.org/).The data thus are maintained, obtain a doi and can be retrieved from that site.

Specific/Minor comments below:

Referee comment 5:

The abstract is a bit long with too many technical or field specific terms that should be introduced (in the introduction), since it makes it difficult to comprehend for the general reader. An example is "While the monthly average mesoclimatic ambient light intensities above the canopy revealed only minor variations: …" This is a well written but complicated sentence for the average reader. Please simplify.

Author comment 5:

The entire abstract was revised for better readability.

Author change in the text 5:

"**Abstract**. In the Amazonian rain forest, major parts of trees and shrubs are covered by epiphytic cryptogams of great taxonomic variety, but their relevance in biosphere-atmosphere exchange, climate processes, and nutrient cycling are largely unknown. As cryptogams are poikilohydric organisms, they are physiologically active only under moist conditions. Thus, information on their water content, as well as temperature and light conditions experienced by them are essential to analyze their impact on local, regional, and even global biogeochemical processes.

In this study, we present long-term data on the microclimatic conditions, including water content, temperature, and light conditions experienced by epiphytic bryophytes along a vertical gradient, which have been collected at the *Amazon Tall Tower Observatory* (*ATTO*) between October 2014 and December 2016. To put these data into perspective, we combine them with ambient "above canopy" climate data. While monthly averages of above-canopy light intensities revealed only minor variation over the course of the year, the light intensities prevailing at the bryophyte surfaces showed major variations depending on canopy height and foliation status of the surrounding vegetation. In the understory (1.5 m), monthly average light intensities were similar throughout the year and individual values were extremely low, remaining below 5 µmol m^{-2} s^{-1} photosynthetic photon flux density over more than 92 % of the time. Temperatures showed only minor variation throughout the year with higher values and larger height-dependent differences during the dry season. The water contents of bryophytes varied depending on precipitation and air humidity. Whereas bryophytes at higher levels were affected by frequent wetting and drying events, those close to the forest floor remained wet over longer time spans during the wet seasons. In general, bryophytes growing close to the forest floor were limited by light availability, while those growing in the canopy had to withstand larger variations in microclimatic conditions, especially during the dry season. Utilizing literature data on the CO_2 gas exchange of lowland bryophytes, their potential physiological activity patterns could be determined. In follow-up studies, these data should be combined with on-site trace gas emission measurements to determine the role of bryophyte communities in climate-relevant trace cycling processes."

Referee comment 6:

Line 12: 1.5 m relative to what (i.e, please include canopy height). For the abstract something general, like 'near-surface' or 'in the understory' is more appropriate.

Author comment 6:

Yes, it is important to set the height of 1.5 m into relation, especially in the abstract. We exchanged "At 1.5 m height" by "in the understory" for more clarity.

Author change in the text 6:

P2 L12: "*In the understory (1.5 m), monthly average*…."

Referee comment 7:

Line 13: instead of saying "low, exceeding less than 8% …" you could say low, remaining below 5 µmol … more than 92% of the time.

Author comment 7:

Yes, it is easier to follow the way you proposed to revise this sentence. We changed it according to your advice.

Author change in the text 7:

P2 L14: "… individual values were extremely low, *remaining below* 5 µmol photosynthetic photon flux density for *more than 92 %* of the time."

Referee comment 8:

Lines 18-19: Dark respiration should occur independent of light (and unless temperatures are very low, which seems unlikely at your site). The references to photosynthesis and respiration are repeatedly incorrect. Photosynthesis and respiration are co-occurring biological processes (in the light), and therefore one may dominate over the other.

Author comment 8:

We agree with the revision, this sentence was expressed in a way, which could easily be misunderstood. As the entire abstract was restructured, this sentence was removed.

Introduction

Referee comment 9:

The first paragraph is a well written introduction to tropical forests, but has little do with the study. Either you should reframe it in the context of epiphytes or omit. Overall, the introduction does not set up the study satisfactorily.

Author comment 9:

The introduction was restructured and sentences were rewritten to better address the topic.

Author changes in the text 9: P2 L24 (Revised introduction):

"Epiphytic cryptogam communities comprise photoautotrophic bryophytes, algae, lichens, and cyanobacteria in varying proportions, growing together with heterotrophic fungi, other bacteria, and archaea. They can colonize plant surfaces in almost all habitats throughout the world (Büdel, 2002; Elbert et al., 2012; Freiberg, 1999). Epiphytic bryophytes in the tropics play a prominent role in environmental nutrient cycling (Coxson et al., 1992; Zotz et al., 1997) and also influence the microclimate within the forest (Porada et al., 2018), thus contributing to the overall fitness of the host plants and the surrounding vegetation (Zartman, 2003). However, they are equally affected by deforestation and an increasing fragmentation (Zartman, 2003; Zotz et al., 1997).

In the Amazonian rain forest, cryptogamic communities mainly occur epiphytically on the stems, branches, and even leaves of trees, and in open forest fractions they may also occur on the soil (Richards, 1954). By 2013, 800 species of mosses and liverworts, 250 lichens species, and 1 800 fungal species have been reported for the Amazon region (Gradstein et al., 2001; Komposch and Hafellner, 2000; Normann et al., 2010; Piepenbring, 2007).

Tropical rain forests are characterized by humid conditions, high temperatures, minor annual fluctuations of temperature, and an immense species diversity of flora and fauna. They have been described to play important roles in the water cycle as well as for carbon, nitrogen, and phosphor fluxes on regional and global scales (Andreae et al., 2015). Up to now, ~ 16 000 tree species have been estimated for the Amazon (ter Steege et al., 2013), but the impact of anthropogenic activities on these numbers is highly uncertain. Similarly, it is also hard to predict, to which extent the ongoing and envisioned changes will still ensure its ecological services as "green lung" and carbon sink of planet Earth (Soepadmo, 1993).

Physiologically, cryptogamic organisms in general and specifically also bryophytes are characterized by their poikilohydric nature, as they do not actively regulate their water status, but passively follow the water conditions of their surrounding environment (Walter and Stadelmann, 1968). In a dry state, many bryophytes can outlast extreme weather conditions, being reactivated by water (Oliver et al., 2005;

Proctor, 2000; Proctor et al., 2007; Seel et al., 1992), and for several species also fog and dew can serve as a source of water (Lancaster et al., 1984; Lange et al., 2006; Lange and Kilian, 1985; Reiter et al., 2008). Accordingly, their physiological activity is primarily regulated by the presence of water and only secondarily by light and temperature (Green and Proctor, 2016).

Referee comment 10:

Pg 3 Line 13: ‘By’ not ‘In’ 2013.

Author comment 10:

Changed accordingly

Referee comment 11:

Pg 4 Line 5: Update references to carbonyl sulfide: (Gimeno et al., 2017; Rastogi et al., 2018).

Author comment 11:

Many thanks for the provision of these additional references, but due to a revision of the introduction, the information on OCS has been omitted.

Methods

Referee comment 12:

Sec. 2.1. A greater description of the site is required. I would recommended starting with site characteristic and then describe the tower and measurements, not the other way around.

Author comment 12:

The advice to start with a description of the forest area and to subsequently characterize the study site itself is a good idea, and we reordered section 2.1. accordingly. However, we refrain from giving a more detailed description of the site, as this is nicely presented by Andreae et al. (2015), which belongs to the same special issue (on ATTO) as the current manuscript.

Author change in the text 12:

P4 L3:” The study site is located on a *terra firme* (plateau) forest area in the Amazonian rain forest, approx. 150 km northeast of Manaus, Brazil. The average annual rainfall is 2 540 mm year^{-1} (de Ribeiro, 1984), reaching its monthly maximum of ~ 335 mm in the wet (February to May) and its minimum of ~ 47 mm in the dry season (August to November) (Pöhlker et al., 2018). These main seasons are linked by transitional periods covering June and July after the wet and December and January after the dry season (Andreae et al., 2015; Martin et al., 2010; Pöhlker et al., 2016). The *terra firme* has an average growth height of ~ 21 meters, a tree density of around 598 trees ha^{-1}, and harbors around 4 590 tree species on an area of ~ 3 784 000 km^2, thus comprising a very high species richness compared to other forest types (McWilliam et al., 1993; ter Steege et al., 2013). The measurements were conducted at the research site *ATTO* (*Amazon Tall Tower Observatory*; S 02° 08.602', W 59° 00.033', 130 m a. s. l.), which has been described in detail by Andreae and co-authors (2015). It comprises one walk-up tower and one mast of 80 m each, which have been operational since 2012, and a 325 m tower, which has been erected in 2015. The ATTO research platform has been established to investigate the functioning of tropical forests within the Earth system. It is operated to conduct basic research on greenhouse gas as well as reactive gas exchange between forests and the atmosphere and contributes to our understanding of climate interactions driven by carbon exchange, atmospheric chemistry, aerosol production, and cloud condensation."

Referee comment 13:

Pg 4 line 13: Remove "The".

Author comment 13:

The word was removed.

Author change in the text 13:

P4 L10: "*Measurements* were conducted at…"

Referee comment 14:

Pg 5 line 2: "were measured" not "are being measured".

Author comment 14:

In this case, we aimed to stress that the *measurements are still running*. Due to this we would like to keep the expression.

Referee comment 15:

P5 Line 5: this seems important for your study and you should describe why sensors were placed where they were placed, in addition to citing the Mota de Oliveira (2013) study.

Author comment 15:

We placed the sensors along a vertical gradient ranging from the understory to the canopy, in order to cover the range of microclimatic conditions experienced by the epiphytic bryophytes as thoroughly as possible. We included a phrase to express this intention.

Author change in the text 15:

P4 L20: “The sensors were placed along a vertical gradient at ~ 1.5, 8, 18, and 23 m above the ground, corresponding to the zones 1 to 4 used by Mota de Oliveira and ter Steege (2015) in order to cover the range of microclimatic conditions experienced by epiphytic bryophytes as thoroughly as possible.”

Referee comment 16:

Pg 6: line 30: Why 60 C? Is this a temperature that these communities experience?

Author comment 16:

Drying the organisms at 60°C until weight consistency is a common procedure to determine the dry weight of these organisms. This is not related to the environmental field conditions, but is a standard method used to obtain a standardized dry weight.

Author change in the text 16:

P7 L12: “The dry weight (*DW*) was determined after drying at 60 °C *until weight consistency was reached (Caesar et al., 2018)*.”

Referee comment 17:

Sec 2.5. Again, some information (a figure ideally) describing the vertical profile of the forest is necessary. That helps put the various sensor heights in perspective.

Author comment 17:

This is a good idea and we prepared a graphical scheme, which is presented in the supplementas Fig. S2 (see below).

Author changes in the text 17:

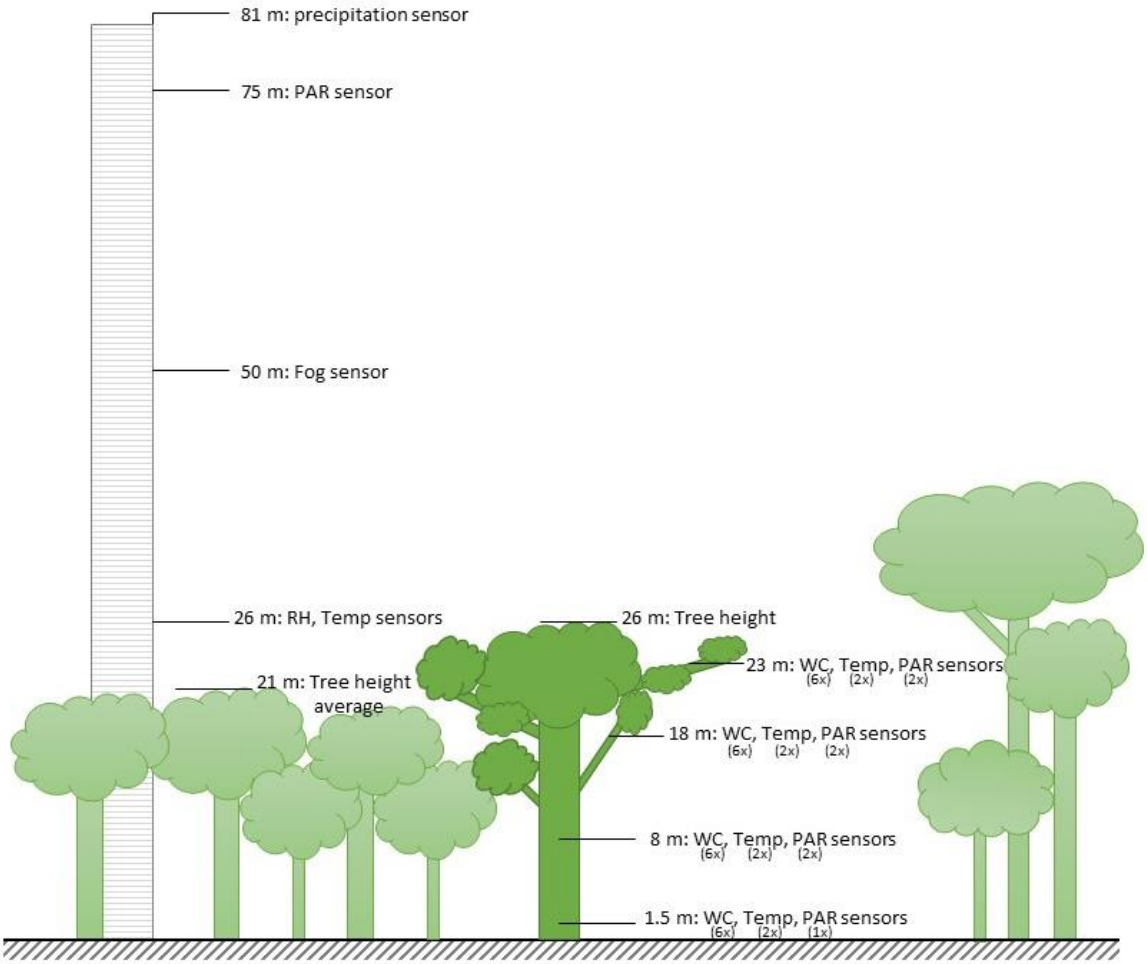

Figure S2: Schematic overview of the sensors installed at different height levels below, within, and above the canopy. The parameters water content (WC) and temperature (Temp) were measured within the bryophyte samples, the light sensors (PAR) were installed directly on top of the thalli. The average tree height of 21 m was determined for the Plateau forest in general.

Referee comment 18:

Lines 15-21: Why were rainfall values gap-filled? Also, isn't the sensor at 1.5 m the least well placed to record rain event. For instance, a small rain event might not even be recorded at 1.5m, as interception must be high in a high LAI forest. Alternatively, there could be time lags between when rainfall occurs at the canopy top and when it is measured by the 1.5 m ht rain gauge.

Author comment 18:

Unfortunately, over the course of the long-term rainfall measurements there are some measurement gaps, which needed to be filled in order to correctly analyze the data.

The rain gauge has been installed at 81 m height on the tower, while the canopy height in this forest is approximately 21 m. Consequently, the rain gauge is placed well above the canopy. As correctly assumed by you, the bryophytes in the understory (1.5 m) might not get watered by light rain events and there is also a delay of several minutes until they get wet compared to the canopy organisms.

Referee comment 19:

Pg 8 L32- Pg 9, L1: Rephrase sentence. Light intensity regulates the balance i.e. the net exchange between photosynthesis and respiration.

Author comment 19:

The sentences were rephrased to make clear that the light triggers, which process might dominate the carbon balance.

Author change in the text 19:

P9 L11: "While the availability of water determines the overall time of physiological activity, the light intensity regulates *whether* net photosynthesis (NP) or dark respiration (DR) *will dominate the overall metabolical balance*. "

Referee comment 20:

Line 14: Respiration takes place at all light levels. IT IS NOT A LIGHT DEPENDANT PROCESS (there can be significant inhibition of respiration at high light levels). Please check this basic tenet of biology.

Author comment 20:

We are aware of the fact that this was not expressed in a correct way. We meant to state that under these condition NET respiration is observed. We know that both photosynthesis and respiration often occur simultaneously and that the net balance is what is being measured. We changed that accordingly.

Author change in the text 20:

P9 L21: "At light intensities below the compensation point and water contents above WCP_1 net respiration *takes place*."

Referee comment 21:

Line 21: Based on *literature*, not literature *data*. Also, please cite the relevant literature.

Author comment 21:

We believe that literature data (i.e. data extracted from the literature) is the correct expression here and thus would like to keep this expression. We added the relevant literature citations.

Author change in the text 21:

P9 L28: "*Based on literature data (Frahm, 1990; Lösch et al., 1994; Wagner et al., 2013),* we calculated the timespans when these key points were passed, utilizing the *5-minute microclimate data.*"

Results: Overall, I do not have issues with the content per se, but as I have stated before this section needs to be majorly revised/expanded. Some minor comments below.

Referee comment 22:

Pg 10 Line 8: Micromet did not depend on years but varied amongst years.

Author comment 22:

Indeed we were not precise enough with our formulation. We rephrased the sentence accordingly.

Author changes in the text 22:

P10 L18: "Over the course of the two years of measurements, the monthly mean values of above-canopy meteorological conditions, the water content, temperature, and light of epiphytic bryophytes varied *between* seasons and years."

Referee comment 23:

Pg 10 Line 18: please define mesoclimate the first time you use this term.

Author comment 23:

Mesoclimate is a standing term describing the climate of a given habitat, covering a side length of some tens or hundreds of meters. We utilized this expression to distinguish the above-canopy climate measurements from the microclimate measurements conducted next to/within the bryophyte thalli. As this expression lead to some confusion, we replaced it by the term "above canopy climate" throughout the text.

Referee comment 24:

Pg 11 Line 30-31: What does this mean? Please elaborate.

Author comment 24:

At 1.5 m height the water content sensors always showed an increase after rain events, whereas this was not always observed for the sensors at the other height levels. This seems not fully logical at first sight, but we can imagine that the thalli growing on one side of the tree are sometimes not hit by the rain if it comes from one side. We could imagine that the rain intercepts with some inclination at the higher levels, whereas close to the ground this inclination is lost. This, however, is only one potential explanation which has not been verified by us.

Referee comment 25:

Pg 12 Sec 3.1.3 header: remove parenthesis

Author comment 25:

Yes, we can remove the parentheses in the header.

Author change in the text 25:

P12 L19: "3.1.3 Diel cycles in different seasons and years along a vertical gradient"

Referee comment 26:

Pg12 Line 13: which 'organisms'. Please specify.

Author comment 26:

Here, the epiphytes, which have been mentioned earlier in the sentence, are meant. We reformulated the sentence.

Author change in the text 26:

P13 L1: "The variability and the diel amplitudes tended to be higher for the epiphytes in the canopy than for *these* in the understory."

Referee comment 27:

Sec. 3.2. The scope of your inference is limited since you do not have replicates on different trees. I do not see this as limitation, but somewhere (probably in the discussion) you need to talk about heterogeneity in the microclimatic environment.

Author comment 27:

Yes, this is right, and we now describe this restriction of the measurements in an additional passage in the Material and Methods section.

Author change in the text 27:

P 4 L28: "Due to constraints in accessibility, all sensors had to be installed on one tree. Thus, we expect that the replicate sensors at each height are not be fully independent and thus the variability could only partly be covered by our current setup."

Referee comment 28:

P13 Lines 13-14. This has been mentioned previously (in Sec. 3.1.).

Author comment 28:

Whereas in the previous sections, we discuss the annual fluctuations of monthly mean values and the seasonal changes between the wet and dry season, the diel cycles are the focus of the current section. Thus, the temperature needs to be discussed under these different aspects and this might give the impression of some repetition. However, we could not find the position where this statement has been made before. Perhaps you can give us a clearer hint on that.

Referee comment 29:

P13 Lines 25 to Pg 14 line 3: This is a well written paragraph but belongs in the discussion.

Author comment 29:

This section was rephrased, according to recalculations and was moved to the discussion section.

Tables

Referee comment 30:

Table 1: Why are these annual means presented? Why are light levels higher at 23 m than at 18m (again discuss heterogeneity)? I still don't have a good grasp of the canopy structure. I do not understand the sensor placement with respect to the canopy structure. Is the 23 m sensor above the canopy top (~ 21m)? Probably not, since light levels seem too low. Also, there seems to be some confusion between relative humidity and water content.

Author comment 30:

The annual means are presented to show the differences between the years, to demonstrate that the climatic conditions change from one year to the next.

The light conditions at the different height levels of the canopy are discussed in the discussion section (see below). The canopy structure and sensor positions have been already described above (comment 17). The tree is approximately 26 m high, which is now also mentioned in the methods section (P 5 L22), thus the sensors from 1.5 to 23 m height are located on top of the bryophytes growing on the stem of the tree.

We clarified this by deleting the RH-data, as they do not really fit here.

Author change in the text 30:

Canopy structure and sensor position: P4 L32: "*Generally, the water content sensors have been placed in four different bryophyte types being heterogeneously distributed along the four height levels. At the height level of 1.5 m the water content sensors were installed in the moss species Sematophyllum subsimplex (5 sensors) and Leucobryum martianum (1 sensor), at 8 m in the species Octoblepharum cocuiense (3 sensors) and cf. Symbiezidium barbiflorum (3 sensors), at 18 and 23 m in the species cf. Symbiezidium barbiflorum (each all 6 sensors). The temperature sensors were installed in the same species at each height, and the light sensors were installed just next to measured species. Furthermore, the sensors were installed with the following orientations: at 1.5 and 8 m vertically along the trunk, at 18 m at the upper side of a slightly sloped branch, and at 23 m at the upper side of a vertical branch. Thus, also the orientation at the stem can influence the water content of the bryophytes, not only the species and the canopy structure.* "

Tree height: P 4 L23: "At each height level, six water content, two temperature, and two light sensors (except for 1.5 m with only one light sensor) were installed in different bryophyte species at the same tree, *measuring a height of approximately 26 m (Table S1b).*"

Relative humidity and water content: Table 1:" Annual mean values, standard deviation (± SD), and statistical significance of the difference between both years, listed for the following parameters: daytime average of photosynthetically active radiation (PAR_{avg}), daily maximum of photosynthetically active radiation (PAR_{max}), *temperature, and water content. For the first three parameters, both above-canopy and microclimatic data (assessed at the different height levels) are shown, whereas for water content only microclimatic data have been collected (a).*"

Referee comment 31:

Table 2. There are no significant differences between seasons for some variables (for e.g., temperature), even though this is alluded to in the results (Pg. 11, line 24).

Author comment 31:

The statement on P11 L24 refers to a significant difference of the temperature between 23 m and above canopy measurements assessed during the dry season, which is listed in Table S5. We changed the text to make this aspect clearer.

Author change in the text 31:

P 12 L3:" At 23 m height, temperatures within bryophytes were frequently higher than the above-canopy values, and during the dry season even the average seasonal temperature of the bryophytes was 0.5°C higher ($p \leq 0.001$) than the above canopy average temperature (Tab. S5 , Fig. S7)."

Figures: Generally, the figures need to be clearer, and larger, since you have several subplots.

Referee comment 32:

Fig 2. PAR and Temperature at different heights are very hard to see. Either summarize differently, or show a mean in this figure and direct to a figure in the supplemental with data from all heights.

Author comment 32:

We tried to adapt the figures for more clarity.

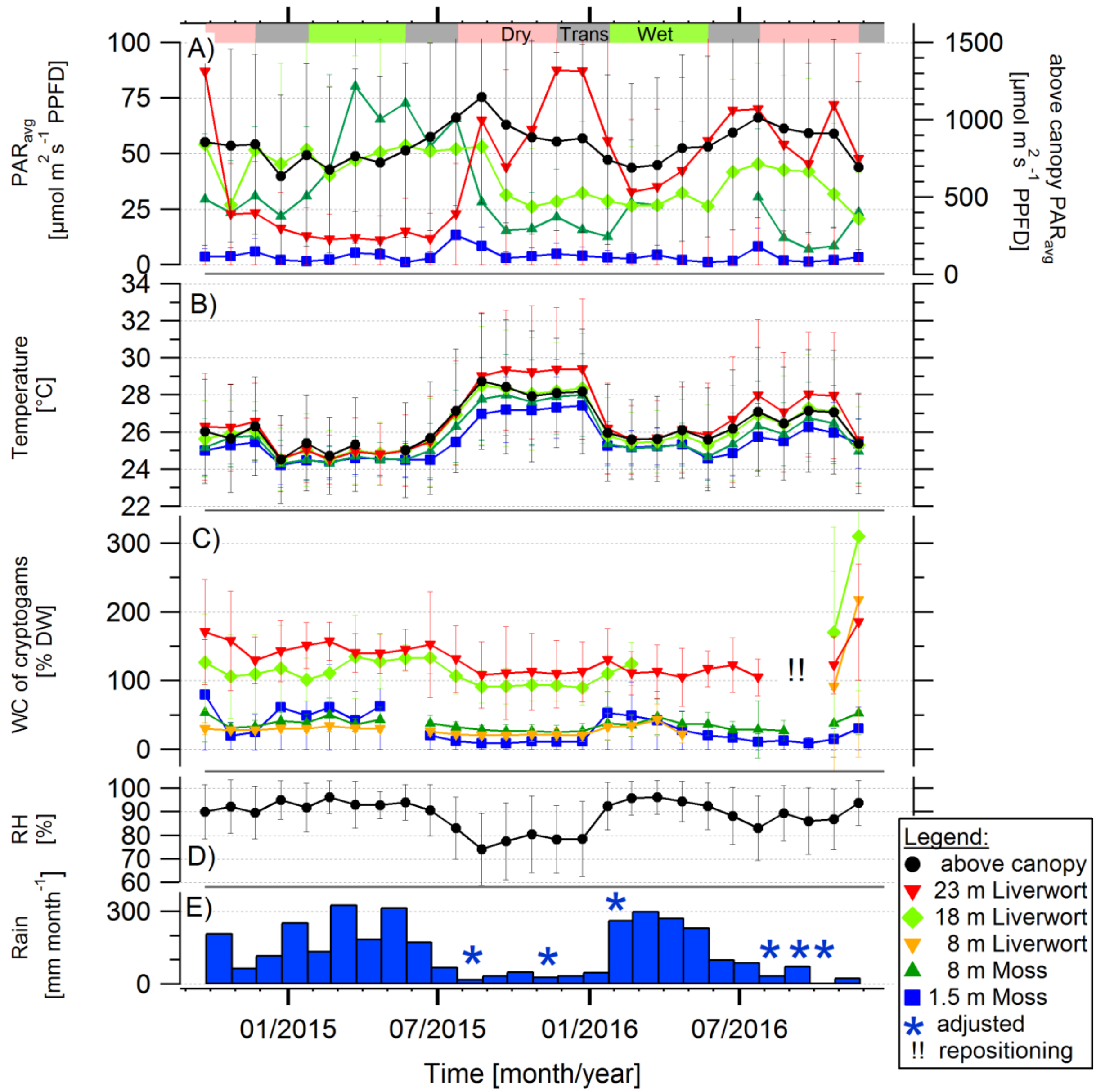

Figure 1: Water content, temperature, and light conditions of bryophytes, and above-canopy meteorological conditions experienced in the Amazonian rain forest. The micrometeorological parameters on top/within epiphytic the cryptogamic communities represent monthly mean values ± SD of (A) average by day (06:00 – 18:00 LT) of photosynthetically active radiation (PAR$_{avg}$) on top, (B) temperature within, and (C) water content of cryptogamic communities. The above-canopy meteorological parameters comprise (A) the monthly mean value of the average by day(06:00 – 18:00 LT) of above-canopy photosynthetically active radiation (PAR$_{avg}$ at 75 m), (B) monthly mean value of above-canopy temperature (at 26 m), (D) monthly mean value of relative air humidity (RH at 26 m

height), and (E) monthly amount of rain. Data of replicate sensors installed within communities at the same height level as 30-minute averages were pooled, while above-canopy parameters were measured with one sensor each. Colored horizontal bars in the upper part of the figure indicate the seasons. Exact values and additional data are presented in Tables S3 and S4.

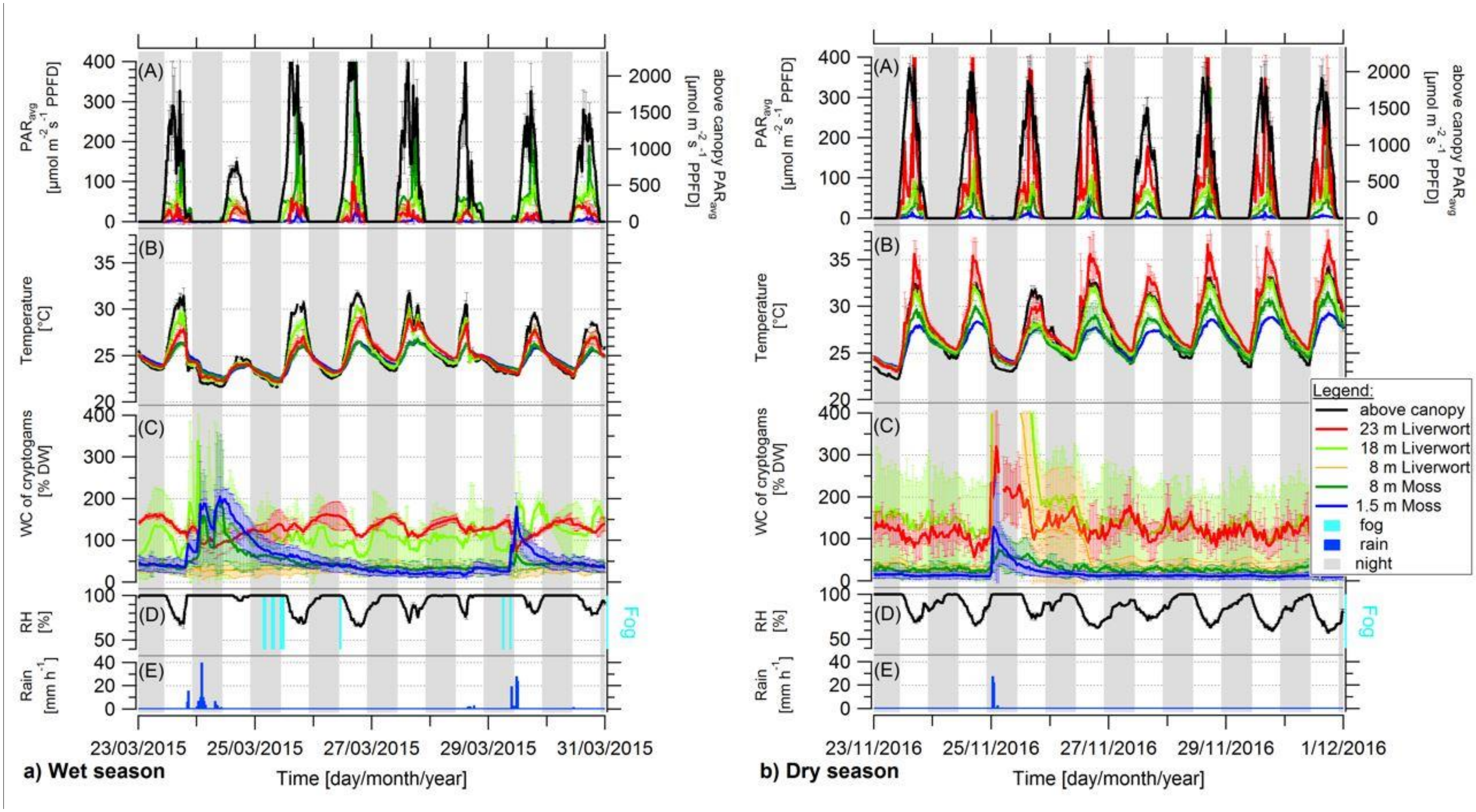

Figure 2: Representative periods during wet and dry season under average conditions showing water content, temperature, and light conditions of bryophytes, and above-canopy meteorological conditions in the Amazonian rain forest. Shown are 8-day periods during (a) the wet season 2015 and (b) the dry season 2016. The micrometeorological parameters on top/within epiphytic cryptogamic communities represent (A) the photosynthetically active radiation (PAR_{avg}) on top, (B) the temperature within, and (C) the water content of cryptogamic communities. The above-canopy meteorological parameters comprise (A) above-canopy photosynthetically active radiation (PAR_{avg} at 75 m), (B) above-canopy temperature (at 26 m), (D) relative air humidity (RH at 26 m height), presence of fog events, and (E) rain. The data show 30-minute averages ± SD except for rain, which shows hourly sums. Data of replicate sensors installed within communities at the same height level were pooled, while above-canopy parameters were measured with one sensor each. The nighttime is shaded in grey (06:00 – 18:00 LT).

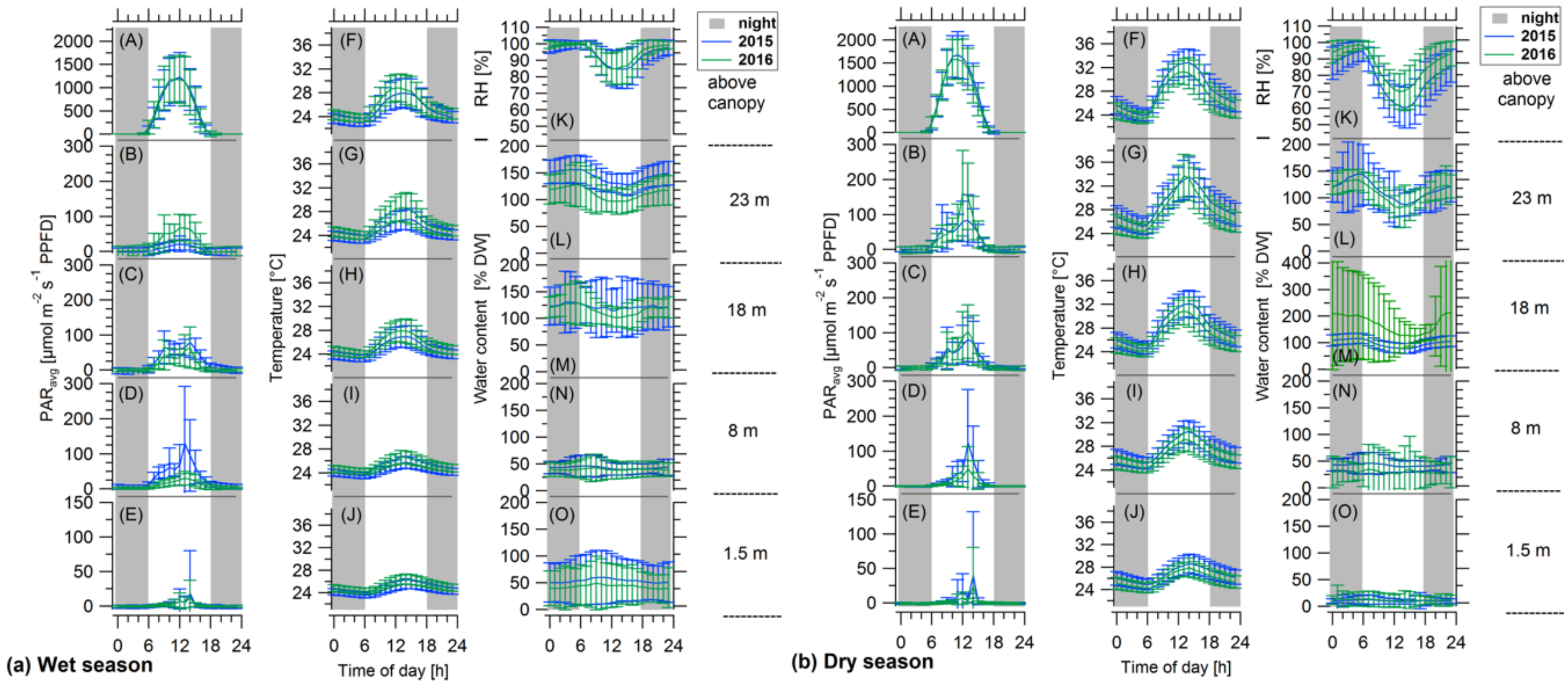

Figure 3: Mean diurnal cycles of water content, temperature, and light condition of bryophytes, and above-canopy meteorological parameters during (a) wet season and (b) dry season of the years 2015 (blue lines) and 2016 (green lines) based on 30-minute intervals. The above-canopy meteorological parameters comprise (A) the above-canopy photosynthetically active radiation (PAR_{avg} at 75 m), (F) the above-canopy temperature (at 26 m), and (K) the relative air humidity (RH at 26 m height). The micrometeorological parameters measured on top/within epiphytic cryptogamic communities comprise (B – E) the photosynthetically active radiation (PAR) on top, (G – J) the temperature within, and (L – O) the water content of cryptogamic communities at different height levels. Diel cycles were calculated from whole seasons and show hourly mean values ± SD. Data of the sensors installed at the same height level were pooled, while the above-canopy parameters were measured with one sensor each. Nighttime is shaded in grey (06:00 – 18:00 LT). Statistical comparisons of maximum and minimum values and diel amplitudes of light, temperature, and humidity between seasons are shown in Table S6 – S8. Comparisons among height levels are presented in Table S9 – Table S11.

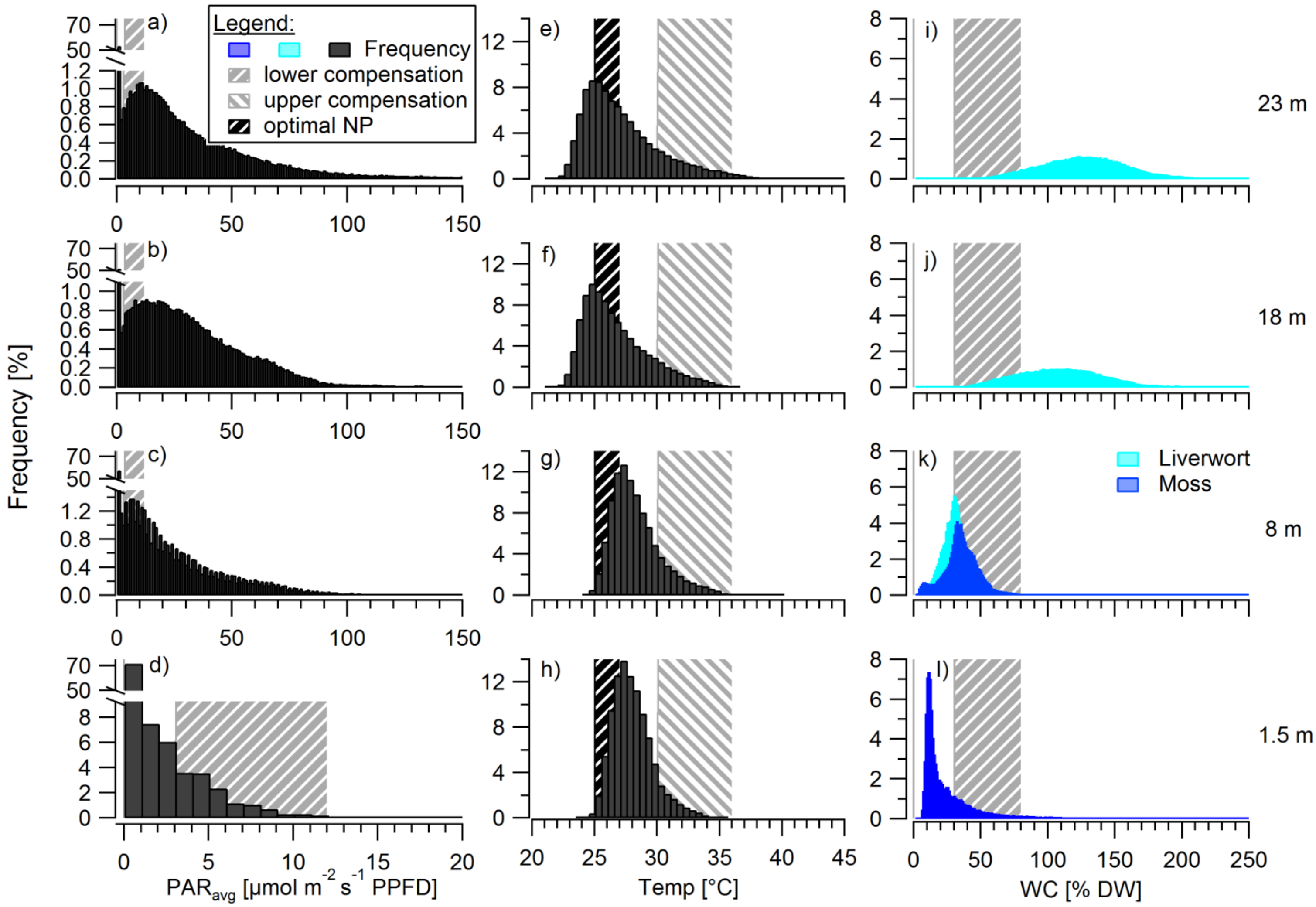

Figure 4: Frequency of photosynthetically active radiation (PAR_{avg}; a – d), temperature (e – h), and water content (i – l) measured on top/within bryophytes at 1.5, 8, 18, and 23 m height within the canopy based on 30-minute intervals. Shaded areas represent the ranges of lower compensation (PAR, water content), upper compensation (temperature), and temperature for optimal net photosynthesis. Value ranges are adopted from Lösch (1994) and Wagner et al., (2013) (Table S3). Bin sizes: PAR: 1 µmol m^{-2} s^{-1} PPFD; temperature: 0.5 °C; WC: 1 %.

Referee comment 33:

Figure 3. This also has too many sub-panels crammed in one figure. In the caption, why do you say ecophysiological, micrometeorological and ambient parameters (the same is actually true of Fig. 1 as well). Which ones are which? Why are they called parameters? What are you trying to parametrize? I make a point about this, because this is one of several instances where words are not chosen carefully. Was humidity not measured at all heights?

Author comment 33:

We are aware of the fact that figure 3 is quite complex and needs some attention to be fully understood. On the other hand, we think that it gives a lot of information and allows direct comparisons between the different parameters and thus we would like to keep it in the current way.

With the term "parameters" we refer to environmental parameters, like temperature, precipitation, light intensity, etc., also called climate parameters or climate factors. We changed the captions to clarify the parameters, which are presented. The relative air humidity was measured at 26 m, just above the canopy, while the water content was measured at all four height levels within the bryophyte cushions.

Author change in the text 33:

Figure 3: "*Mean diurnal cycles of water content, temperature, and light condition of bryophytes, and above-canopy* meteorological parameters …"

Referee comment 34:

Figure 4. The histograms are informative but the information provided in the various shaded regions is extremely hard to follow. In the end, I do not understand what the authors are trying to convey. Why is the y-axis broken in the histograms in the left most panel?

Author comment 34:

Figure 4 was adapted to make it clearer and easier comprehensible.

The y-axis in the left-hand panel (PAR) is broken, as the lowest light intensity was reached at a frequency between 50 and 70%. All the higher light intensities occurred at frequencies of only a few or even below 1%. To show both the high and low frequencies at good resolution, we decided to use a broken y-axis.

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