



Supplement of

Microclimatic conditions and water content fluctuations experienced by epiphytic bryophytes in an Amazonian rain forest

Nina Löbs et al.

Correspondence to: Nina Löbs (n.loebs@mpic.de) and Bettina Weber (bettina.weber@uni-graz.at)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.

Microclimatic conditions and water content fluctuations experienced by epiphytic bryophytes in an Amazonian rain forest

5 Contents:

Figures S1 – S13 Tables S1 – S7



Figure S1: Examples of the temperature sensor (A), light sensor (B), and water content sensor (C) installed in epiphytic bryophytes at the ATTO site. The little arrows show the area of detection, i.e. the sensor tip of the temperature sensor, the area just below the white PTFE cap of the light sensor, and the two inner pins of the water content sensor.



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.



Figure S3: The four bryophyte species being used for installation of the sensors of the microclimate station. (A, D, G, J, K) overview, (B, H, L) leaf, (C, F, I) cell form, and (E, M) cross section of a leaf.



Figure S4: Overview pictures of microsensor tree and exemplary bryophyte samples with installed water content sensors at the three height levels.











Figure S5: Long-term measurements of precipitation, electrical conductivity, and the calculated water content. All the sensors utilized for further calculations are shown: (a, b, c, d) at 23 m height, (e, f, g) at the 8 m height, and (h, i, j, k, l, m) at 1.5 m height. Gaps in the dataset correspond to maintenance periods.



Figure S6: Temperature within bryophytes compared to the above-canopy temperature. The temperature within bryophytes was measured at 1.5 m, 8 m, and 23 m, while the above-canopy temperature was measured at 26 m height on the tower. The data are presented per height zone and also pooled together in the lowest panel. Data present 30-minute averages with linear fits, of the function y = a + bx, with the coefficients (± 1 std. dev.) and the R² are given in the figure for each height level.





Figure S7: Representative periods during wet and dry season under the influence of El Niño, showing light conditions (PAR), temperature, and water content (WC) experienced by bryophytes, and abovecanopy meteorological conditions in the Amazonian rain forest. Shown are 8-day periods during (a) the wet season 2016 and (b) the dry season 2015. The micrometeorological parameters on top/within epiphytic cryptogamic communities represent (A) the photosynthetically active radiation (PAR) on top, (B) the temperature within, and (C) the water content of cryptogamic communities. The above-canopy meteorological parameters comprise (A) the above-canopy photosynthetically active radiation (PAR at 75 m), (B) the above-canopy temperature (at 26 m), (D) the relative air humidity (RH at 26 m), the presence of fog events, and (E) the rain amount. The data show 30-minute averages \pm 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

10

is shaded in grey color (18:00–06:00 LT).



Figure S8: Correlation between the water content (WC) and the rain amount in the preceding 24 h. Linear trendline with formula added to illustrate the relationship between both parameters.



Figure S9: Exemplary daily (micro-) climatic conditions at the canopy level, showing the WC values of the three sensors at 23 m [%] (A), the dew point spread at 23 m [°C] (B), and the environmental factors relative humidity RH[%], temperature T [°C] and direct normal irradiance DNI [W m⁻²] measured at 26 m (C).



Figure S10: Diel dew point spread at 1.5 m and 23 m height levels in a 24-h cycle, illustrating the difference between the temperature of the substrate (T_s) and the dew point of the surrounding air (T_d). If the suface temperature is lower than the dew point of the surrounding air (values below red line) condensation might occur.



Figure S11: Characteristic sequence of (micro-) climatic conditions during the dry and the wet season at (A) 23 m and (B) 1.5 m height. In the plots the relative air humidity [%], ambient and bryophyte temperature [°C], water content of the bryophytes [% dry weight], and dew point spread [°C] are shown.



Figure S12: Exemplary (micro-) meteorological data comprising dewpoint events at (A) 23 m and (B) 1.5 m height. In the plots, the dew point spread [°C], precipitation $[mm h^{-1}]$, relative humidity [%], and the water content [% dry weight] are shown.

Figure S13: Temperature conditions of bryophytes related to their water content. The temperature was measured in bryophytes at different height levels along the tree. Data presented as 30-minute averages.

Table S1: Height of installation, minimum and maximum values of the individual sensors of the microclimate station measuring water content, temperature, and light. For the water content sensors, also the bryophyte species are given. Based on 30-minute averages.

Sensor No	Height	Water of	content	Bryophyte species
	[m]	[% DW]		
		min	max	
Sensor 01	1.5	0	763	Sematophyllum subsimplex
Sensor 02	1.5	0	763	Sematophyllum subsimplex
Sensor 03	1.5	0	763	Sematophyllum subsimplex
Sensor 04	1.5	0	1373	Leucobryum martianum
Sensor 05	1.5	0	763	Sematophyllum subsimplex
Sensor 06	1.5	0	763	Sematophyllum subsimplex
Sensor 09	8	0	1318	Octoblepharum cocuiense
Sensor 10	8	0	1318	Octoblepharum cocuiense
Sensor 11	8	0	1658	Symbiezidium barbiflorum
Sensor 21	23	0	1658	Symbiezidium barbiflorum
Sensor 23	23	0	1658	Symbiezidium barbiflorum
Sensor 24	23	0	1658	Symbiezidium barbiflorum
Sensor No	Height	Tempe	rature	
	[m]	[°(C]	
		min	max	
Sensor 01	1.5	21.1	36.3	
Sensor 02	1.5	21.4	39.4	
Sensor 03	8	21.6	34.7	
Sensor 04	8	20.9	46.3	
Sensor 07	23	20.8	41.2	
Sensor 08	23	20.3	48.7	
	Height	PA	R	
	[m]	[µmol m ⁻² s ⁻¹]		
		min	max	
Sensor 01	1.5	0	634	
Sensor 02	8	0	569	
Sensor 03	8	0	1121	
Sensor 06	23	0	654	
Sensor 07	23	0	767	

Table S2: Water content range measured during the calibration in the laboratory for the different replicates of the four bryophyte species. Listed are the minimum and maximum water content values (WC) measured at full water saturation (WC_{max}) and in the end of drying when weight stability was reached over more than 5 minutes (WC_{min}). Data shown for each replicate (1–4) and the species average (all).

	Replicate		
Species	sample	WC_{min}	WC _{max}
Leucobryum martianum	1	32	1487
Leucobryum martianum	2	10	931
Leucobryum martianum	3	10	1241
Leucobryum martianum	4	7	1834
Sematophyllum subsimplex	1	14	614
Sematophyllum subsimplex	2	14	698
Sematophyllum subsimplex	3	14	468
Sematophyllum subsimplex	4	14	459
Sematophyllum subsimplex	5	7	1576
Symbiezidium barbiflorum	1	15	1657
Symbiezidium barbiflorum	2	15	1982
Symbiezidium barbiflorum	3	15	1581
Symbiezidium barbiflorum	4	22	1412
Octoblepharum cocuiense	1	23	742
Octoblepharum cocuiense	2	16	870
Octoblepharum cocuiense	3	6	2342
Leucobryum martianum	all	15	1373
Sematophyllum subsimplex	all	13	763
Symbiezidium barbiflorum	all	16	1658
Octoblepharum cocuiense	all	15	1318

Table S3: Monthly mean values and standard deviations (\pm SD) of photosynthetically active radiation (PAR_{avg} daytime, measured at 75 m), daily maxima of photosynthetically active radiation (PAR_{max}), temperature (measured at 26 m), and relative humidity (RH, measured at 26 m). Rainfall is presented as the monthly amounts and the percentage of days with rain (measured at 81 m), and also the percentage of days when rain detection malfunctioned are listed. Fog events are given as the percentage of days. Dry season data are shaded in red, wet season data in blue and transitional periods are unshaded. Due to data gaps in the measured rain data (shown in brackets) values for 21 days of rain were also extrapolated from existing data as described in methods section (values behind data in brackets). Values were calculated from 30-minute intervals. Fog has not being recorded in the time ranges of 31.05. – 20.10.2015, 30.04. – 06.07.2016, 01.09. – 31.12.2016 due to malfunction of the device, thus the last column provides data about the number of operational days per month. (*) Gaps in the data record due to malfunction of the device.

Month	PARava	g daytime	PAR	max	Temperature		RH		Rain	Rain	Defect on rain	Fog	Days with
Monui	[µmo]	l m ⁻² s ⁻¹]	[µmol n	$1^{-2} s^{-1}$]	[°C]		[%	5]	[mm month ⁻¹]	[% days]	detection	[% days]	fog data
	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD			[% days]		
Oct 2014	857	668	2201	509	26.0	2.8	90	11	212	58	0	55	30
Nov 2014	832	624	2082	423	25.6	2.9	92	11	70	57	0	53	30
Dec 2014	843	582	2140	346	26.3	2.7	90	11	123	42	0	42	30
Jan 2015	637	525	1747	735	24.5	2.4	95	8	259	71	0	71	29
Feb 2015	774	589	2058	600	25.4	2.6	92	10	140	64	0	46	28
Mar 2015	680	534	2038	575	24.7	2.1	96	7	331	87	0	77	31
Apr 2015	766	564	2155	463	25.3	2.5	93	10	189	80	0	40	29
May 2015	725	559	2103	425	27.2	n.a.	93	6	320	90	0	58	30
Jun 2015	804	562	2237	128	25.0	2.3	94	8	178	80	0	0*	0
Jul 2015	892	605	2238	188	25.7	3.0	91	11	74	65	0	0*	0
Aug 2015	1017	636	1722	957	27.1	3.3	83	13	(23) 32*	23	23	0*	0
Sep 2015	1148	687	2242	467	28.7	3.7	74	15	38	13	20	0*	0
Oct 2015	968	635	2072	514	28.4	3.6	78	16	55	35	3	13*	11
Nov 2015	887	624	1859	769	27.9	3.5	81	16	(33) 37*	30	17	23	28
Dec 2015	862	575	2074	304	28.1	3.0	78	14	38	26	3	6	31
Jan 2016	882	606	2175	270	28.2	3.4	78	16	52	48	0	13	31
Feb 2016	743	550	1928	679	25.9	2.6	93	10	(267) 341*	79	52	48	29
Mar 2016	692	545	2041	545	25.6	2.1	96	7	304	90	0	77	31
Apr 2016	709	564	2088	443	25.6	2.3	96	7	277	87	0	73	28
May 2016	817	603	2230	405	26.1	2.6	94	8	236	90	0	0*	0
Jun 2016	828	584	2178	261	25.6	2.8	92	10	105	57	0	0*	0
Jul 2016	917	629	2253	118	26.2	3.2	88	12	92	58	0	26*	26
Aug 2016	1016	648	2146	593	27.1	3.5	83	14	40	32	3	16	31
Sep 2016	947	662	2230	543	26.5	3.1	89	12	(77) 96*	50	17	0*	0
Oct 2016	915	641	2323	192	27.1	3.3	86	14	(1) 9*	23	23	0*	0
Nov 2016	911	610	2227	217	27.1	3.3	87	13	(30) 89*	20	13	0*	0
Dec 2016	694	553	1955	503	25.4	2.7	94	10	223	71	0	0*	0

Table S4: Parameters determining the time range of photosynthesis and respiration. The ranges of values defining the lower water compensation point (WCP), the lower light compensation point (LCP_l), the temperature for optimal net photosynthesis (T_{opt}), and the upper temperature compensation point (TCP) as relevant parameters have been extracted from published studies conducted at various study sites in the tropical rain forest.

5

Parameter	Range of values	Reference	Study site
WCP	30–80 % DW	Wagner et al 2013	Panama, lowland rain forest, 0 m
LCP ₁	3-12 µmol m ⁻² s ⁻¹	Lösch et al. 1994	Zaire, lowland rain forest, 800 m
T_{opt}	24–27 °C	Wagner et al 2013	Panama, lowland rain forest, 0 m
TCP	30–36 °C	Wagner et al 2013	Panama, lowland rain forest, 0 m

Table S5: Monthly mean values and standard deviations (\pm SD) of the photosynthetically active radiation (PAR_{avg} daytime), the daily maxima of photosynthetically active radiation (PAR_{max}), temperature, and water content of bryophytes at three height levels. Dry season data are shaded in red, wet season data in blue and transitional periods are unshaded. Values were calculated from 30-minute intervals. N.a.: data not available.

Manth		PARavg	daytime	e[µmol	m ⁻² s ⁻¹]		PAR _{max} [µmol m ⁻² s ⁻¹]					Temperature [°C]				Water content [% DW]								
Month	1.5	5 m	8 1	m	23	m	1.5	m	8	m	23	m	1.5	5 m	8 1	m	23	m	1.5 m	Moss	8 m I	M&L	23 m Li	verwort
	Mean	\pmSD	Mean	\pm SD	Mean	\pm SD	Mean	\pmSD	Mean	\pmSD	Mean	\pmSD	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD	Mean	\pm SD
Oct 2014	4	8	30	31	88	90	75	105	285	231	624	286	25.0	1.3	25.2	1.6	26.3	2.9	115	107	110	111	42	20
Nov 2014	4	11	23	32	24	37	142	131	396	321	378	275	25.3	1.2	25.7	1.4	26.2	2.3	38	30	53	16	42	20
Dec 2014	6	18	31	50	25	33	236	172	435	228	346	235	25.4	1.1	25.8	1.3	26.6	2.1	49	48	56	20	35	7
Jan 2015	3	8	22	28	20	27	155	96	341	219	341	246	24.2	1.1	24.3	1.3	24.6	1.8	129	113	76	32	39	12
Feb 2015	2	3	31	21	16	17	46	33	173	183	234	244	24.5	1.0	24.5	1.1	25.0	1.8	87	67	69	33	38	8
Mar 2015	3	4	43	35	16	15	45	55	292	159	128	117	24.4	0.9	24.3	0.9	24.5	1.3	106	65	102	64	38	6
Apr 2015	6	20	80	105	16	18	346	310	480	231	241	231	24.6	0.9	24.7	1.1	24.9	1.8	79	65	73	31	39	8
May 2015	6	32	66	71	16	17	634	428	282	236	146	137	24.6	0.9	24.5	0.9	24.8	1.7	130	90	103	58	39	8
Jun 2015	2	3	73	64	18	20	42	51	214	125	177	141	24.5	0.9	24.5	1.0	25.0	1.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Jul 2015	3	12	54	73	15	18	168	178	727	301	152	144	24.5	1.1	25.0	1.5	25.5	2.5	37	24	103	45	49	23
Aug 2015	13	56	66	115	24	23	601	414	746	193	227	170	25.4	1.2	26.3	2.0	27.0	2.8	20	10	67	17	42	21
Sep 2015	9	21	28	47	65	66	248	204	403	224	492	229	27.0	1.7	27.8	2.2	29.0	3.4	13	17	60	15	36	18
Oct 2015	3	4	15	15	44	30	53	47	128	99	221	157	27.2	1.8	28.0	2.2	29.4	3.2	13	16	36	21	43	52
Nov 2015	4	7	16	25	61	64	82	95	315	151	475	208	27.2	1.9	27.6	2.3	29.2	3.6	16	14	51	30	37	32
Dec 2015	5	11	22	35	88	103	112	116	308	171	645	250	27.3	1.6	27.9	2.0	29.4	3.4	15	11	48	24	35	18
Jan 2016	4	7	16	21	88	103	72	91	177	143	692	294	27.4	1.8	28.0	2.2	29.4	3.8	16	14	51	31	37	16
Feb 2016	3	4	13	11	57	46	46	54	79	76	388	237	25.2	1.0	25.4	1.2	26.2	2.5	80	93	99	80	43	16
Mar 2016	3	7	28	15	37	33	102	125	107	80	268	215	25.2	0.9	25.1	0.9	25.6	1.8	74	68	91	49	41	13
Apr 2016	5	15	27	19	38	31	192	199	59	27	270	203	25.2	1.0	25.2	1.1	25.7	2.0	63	45	131	85	43	14
May 2016	3	7	n.a.	n.a.	45	41	114	109	n.a.	n.a.	286	209	25.3	1.0	25.3	1.2	26.1	2.3	42	33	75	39	44	16
Jun 2016	2	2	n.a.	n.a.	58	68	25	34	n.a.	n.a.	416	199	24.6	1.1	24.6	1.3	25.8	2.8	31	18	61	30	45	13
Jul 2016	2	4	n.a.	n.a.	72	86	30	44	n.a.	n.a.	527	204	24.8	1.2	25.3	1.7	26.7	3.4	24	22	52	21	53	36
Aug 2016	9	34	31	52	71	94	319	216	340	241	614	256	25.7	1.8	26.3	2.4	28.0	4.1	22	28	59	99	59	130
Sep 2016	3	7	13	24	55	69	102	84	250	137	508	244	25.5	1.3	25.9	1.7	27.1	3.3	28	40	52	39	67	111
Oct 2016	2	3	7	9	47	54	35	28	106	71	421	219	26.2	1.6	26.8	1.9	28.0	3.4	17	9	45	18	43	38
Nov 2016	3	5	9	13	73	85	59	51	172	114	606	251	25.9	1.7	26.5	2.1	28.0	3.4	18	20	49	49	44	37
Dec 2016	4	12	24	38	52	56	156	131	361	282	457	274	25.4	1.3	25.0	1.7	25.6	2.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table S6: Mean values and standard deviations (\pm SD) of the daily maxima of photosynthetically active radiation (PAR_{max}) for each height level shown for 2015 and 2016, considering that 2015 was an El Niño year (additional information to Table 1).

	PAR _{max} [µmol m ⁻² s ⁻¹]							
Height	201	15	201	.6				
	Mean	\pm SD	Mean	± SD				
above canopy	1766	415	1842	364				
23 m	125	123	226	140				
8 m	186	195	68	90				
1.5 m	49	89	29	45				

Table S7: Mean values and standard deviations (\pm SD) of the daily maxima of photosynthetically active radiation (PAR_{max}) for each height level shown for the different seasons (additional information to Table 2).

Height	PAR _{max}								
8	[µm	ol m ⁻² s ⁻¹]							
[m]	Mean	\pm SD							
Wet season									
above-canopy	1687	431							
23 m	245	82							
8 m	210	151							
1.5 m	191	206							
Transitional season Wet-Dry									
above-canopy	1855	233							
23 m	318	183							
8 m	471	363							
1.5 m	66	68							
Dry season									
above-canopy	1924	370							
23 m	457	147							
8 m	314	184							
1.5 m	172	177							
Transitional season Dry-Wet									
above-canopy	1691	407							
23 m	496	165							
8 m	324	95							
1.5 m	146	61							