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SupplementaryMaterials:

The Impact of Variable Horizon Shade on the Growing Season Energy Budget of a Subalpine Headwater Wetland

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Surface energy budget closure [1] varied during the growing season at our site with an average closure of 68 % from Green-Up to the Late Growing Season (Table S3). At our site, the Snowmelt period had a very low energy budget closure (8%) because of a low ground heat flux, due to sensors being buried under snow, and northwesterly winds originating upslope from the area of our site with the thickest snowpack and most shading. However, we did not focus on the Snowmelt period in our analysis, only using it to determine the start of Green-Up. During the Green-Up and Peak Growing Season periods fluxes mostly came from the south-east region that is occupied by dense vegetation. The energy budget closure during these periods was 65% and 74%, respectively. During the Late Growing Season most of the signal came from the north-west direction and the energy budget closure was 66%. It appears that the highest closure occurs when the canopy is fully developed and active (Peak Growing Season). Overall, our energy budget closure values were within the range and near the mean value (53 to 99%, mean of 79%) reported across 22 sites FLUXNET sites from different ecosystems with contrasting climates [2]. Although advection was not assessed in our study, due to logistical constraints, we acknowledge that the transition between downslope and upslope winds may have influenced the horizontal transport of air and resulted in warm air advection at our site [3]. This may have affected energy budget closure during the periods of Snowmelt and Late Growing Season when winds were predominantly north-west. Hiller et al [3] reported energy budget closure of 74±2% during their growing season study of an alpine meadow in the Swiss Alps. Our Peak Growing season energy budget closure was comparable and lower during the shoulder seasons. Possible influence of advection at our site would be interesting to investigate in future studies.

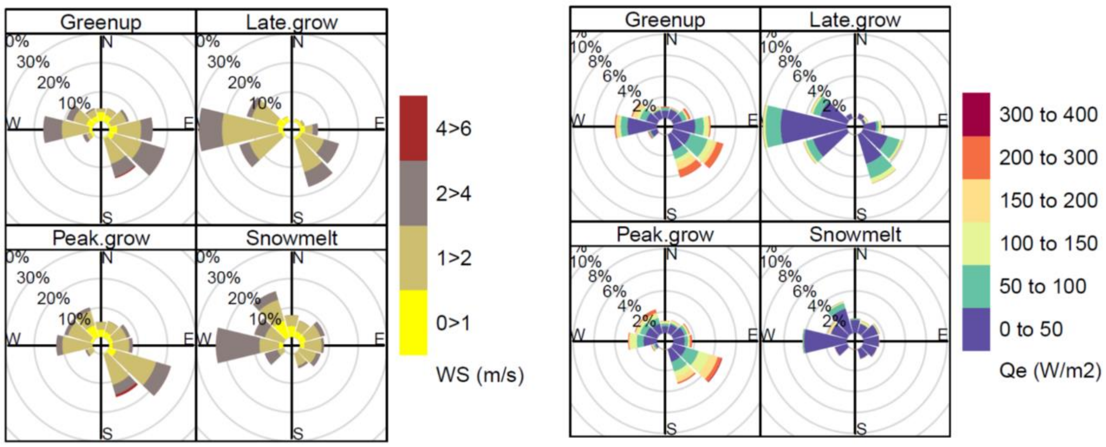

Figure S1. Rose diagrams showing the frequency distribution and cardinal direction of wind speed (WS in m/s) and latent heat flux (Qe in W/m²) measured by the meteorological/EC station at our study site. Data is shown by physiological seasons (n = 849, QA/QC'd, non-gapfilled data for half-hours were Qe data was present).

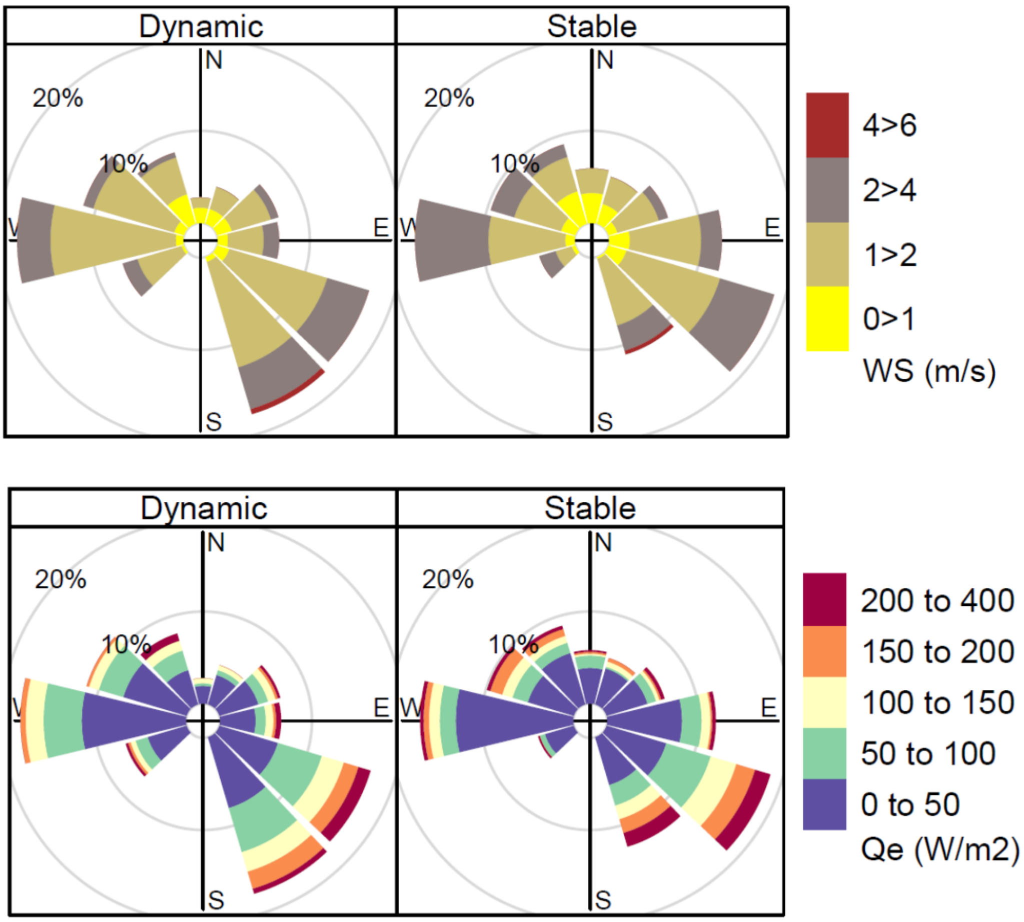

Figure S2. Rose diagrams showing the frequency distribution and cardinal direction of wind speed (WS in m/s) and latent heat flux (Qe in W/m²) measured by the meteorological/EC station at our study site. Data is shown by Shade periods (n=849, QA/QC'd, non-gapfilled data for half-hours were Qe data was present).

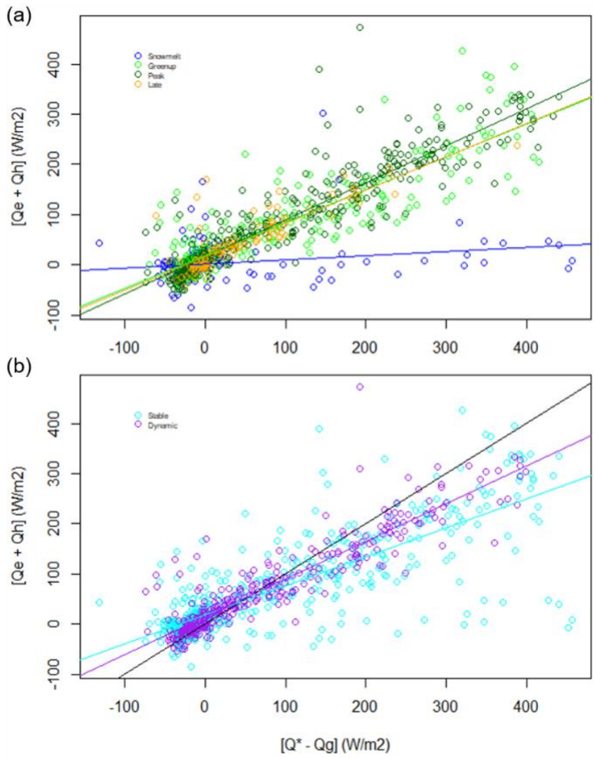

Figure S3. a) Comparison of Energy Balance Closure for the different seasons during our study. The red line is a 1:1 line. The rest of the lines represent linear fits to each respective seasonal scatter, corresponding to the colours of each seasonal symbol. During all seasons, the energy balance closure was below one. The worst fit was during *Snowmelt* season. The corresponding slopes and intercepts for these fits are provided in Table A3 of the Appendix. **b**) Comparison of Energy Balance Closure for the different Shade periods during our study. The black line is a 1:1 line. The rest of the lines represent linear fits to each respective shaded period scatter, corresponding to the colours of each symbol. During both periods, the energy balance closure was below one. The corresponding slopes and intercepts for these fits are provided in Table S3 of the Appendix.

Table S1. Correlation matrix between key continuous variables during Peak Growing season (those in red were not used in model runs to avoid collinearity).

	PAR	Qnet	Tair	rH	VPD	Tsoil.2cm	Ts.5cm	Ts.10cm	Ts.avg.2to10cm	SM.avg	Qg	Qe	ET
PAR	1.00												
Qnet	0.98	1.00											
Tair	0.39	0.35	1.00										
rH	−0.28	−0.24	−0.79	1.00									
VPD	0.33	0.29	0.94	−0.88	1.00								
Tsoil.2cm	0.55	0.50	0.71	−0.42	0.60	1.00							
Ts.5cm	−0.02	−0.07	0.60	−0.34	0.52	0.78	1.00						
Ts.10cm	−0.40	−0.43	0.35	−0.20	0.32	0.37	0.85	1.00					
Ts.avg.2to10cm	0.21	0.16	0.68	−0.40	0.59	0.91	0.97	0.72	1.00				
SM.avg	0.22	0.19	0.04	0.08	−0.04	0.16	−0.01	−0.22	0.04	1.00			
Qg	0.95	0.95	0.45	−0.27	0.36	0.66	0.08	−0.35	0.32	0.21	1.00		
Qe	0.91	0.89	0.50	−0.37	0.45	0.60	0.09	−0.28	0.31	0.25	0.91	1.00	
ET	0.91	0.89	0.50	−0.37	0.45	0.60	0.09	− 0.28	0.31	0.25	0.91	1.00	1.00

Table S2. Evaluation of individual explanatory variable contributions to model fit. These models are generalized additive models. AIC is Akaike's Information Criterion and BIC is the Bayesian Information Criterion, used in model selection. The 1:1 relationships were tested by plotting observed Qe values against those predicted by each model.

	df	AIC	delta AIC	BIC	delta BIC	1:1 adj R2
Full model Qe = f(PAR, VPD, SM, Shade)	9	1115		1149		0.8768
as Full, but without PAR variable	15	1607	492	1662	513	0.3389
as Full, but without VPD variable	9	1158	43	1193	44	0.8534
as Full, but without SM variable	9	1132	17	1167	18	0.8632
as Full, but without Shade variable	9	1120	5	1152	3	0.8728

Table S3. Linear fits to Energy Balance Closure Scatter Plots in Figure S3. Not significant at p = 0.05.

Period	**n-sample size**	**m- slope**	**b-intercept**	**R^2**
All	849	0.63	17.19	0.70
Snowmelt	134	0.08	1.60*	0.04
Green up	255	0.65	18.60	0.78
Peak growing	347	0.74	16.60	0.84
Late growing	113	0.66	16.26	0.72
Stable shade	490	0.58	17.76	0.64
Dynamic shade	359	0.73	14.98	0.81

*not significant at p = 0.05.

Reference:

1. Mauder, M.; Foken, T.; Cuxart, J.. Surface-energy-balance closure over land: a review. *Boundary-Layer Meteorology.* **2020**, *177*, 395-426.
2. Wilson, K.; Goldstein, A.; Falge, E.; Aubinet, M.; Baldocchi, D.; Berbigier, P.; Bernhofer, C.; Ceulemans, R.; Dolman, H.; Field, C.; et al. Energy balance closure at FLUXNET sites. *Agric. For. Meteorol.* **2002**, *113*, 223–243.
3. Hiller, R.; Zeeman, M.J.; Eugster, W. Eddy-Covariance Flux Measurements in the Complex Terrain of an Alpine Valley in Switzerland. *Bound. Layer Meteorol.* **2008**, *127*, 449–467.