1 Supplementary tables

Table S1. Calibrated parameters

Symbol	Parameter Name	Unit	Equation (cf. Table S2)	Module	Definition	Min	Max	Literature or default value
Δz_{cov}	CritDepthSnowCover	m	4.7	Snow coverage	The thickness of mean snow height that corresponds to a complete cover of the soil.	$1 \cdot 10^{-3}$	0.02	0.01 (default value)
m_{Rmin}	MeltCoefGlobRad	kg J^{-1}	4.10	Snow melt dependency on radiation	Coefficient in the global radiation response of the empirical snow melt function.	$2.3 \cdot 10^{-7}$	$3 \cdot 10^{-7}$	1.5·10-7 (default value)
f_{qh}	MeltCoefSoilHeatF		4.8	Snow melt dependency on soil heat	Scaling coefficient for the contribution of heat flow from ground on the melting of the snow in the empirical snow melt function.	0.3	0.7	0.5 (default value)
S_{dw}	DensityCoefMass	m^{-1}	4.5	Snow: density coefficient of old snow	Mass coefficient in the calculation of snow density as a function of liquid and ice content in the "old" snow pack.	0.6	1	0.5 (default value)
s_{dl}	DensityCoefWater	kg m^{-3}	4.5	Snow: density dependence on liquid an ice content	Liquid water coefficient in the calculation of snow density as a function of liquid and ice content. The snow density increase with this value when the liquid water content in the snow pack becomes equal to the total retention capacity	160	210	200 (default value)
ρ_{smin}	DensityOfNewSnow	kg m^{-3}	4.3	Snow: density of new snow	Density of new snow.	90	120	100 (default value)
m_T	MeltCoefAirTemp	kg $°C^{-1}$ m^{-2} day^{-1}	4.9	Snow: melting dependency to temperature	Coefficient for temperature dependance in the empirical snow melt function.	2.5	4	A value of 2 is normal for forests. Similar as for MeltCoefGlobRad a two or three fold increase is expected if adaptation to an open filed is to be done (Jansson and Karlberg 2010).
T_{RainL}	OnlyRainPrecTemp		4.4	Snow: temperature treshold for rain:snow	Above this temperature all precipitation is rain.	1.7	2.2	2 (default value)
h_{com}	Common value	mm day^{-1}	6.11	Soil hydraulic conductivity under saturated conditions	Unsaturated matrix conductivity dependency on total saturated conductivity	0.01	100	10 (default value)
ψ_a	Air Entry(1)	cm	6.8	Soil hydraulic properties: shape of water retention in the upper horizon	Air-entry tension. As this was the only calibrated parameter defining the shape pF-curve, it determines unsaturated water distribution in the soil including capillary rise.	1 (3)	8 (10)	Range received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin, 2001); Values in bracket were used for soil horizons < −30 cm
d_p	DrainSpacing	m	6.12	Soil hydrology: drainage distance	Characteristic distance between drainage pipes, denominator when estimating the gradient necessary for the calculation of the horizontal water flow to drainage pipe	30	330	site specific estimation

Symbol	Parameter Name	Unit	Equation (cf. Table S2)	Module	Definition	Min	Max	Literature or default value
$g_{max, vasc}$	ConductMax(1)	m^2 s^{-1}	2.10	Transpiration efficiency	Transpiration coefficient for vascular plants: the maximal conductance of fully open stomata in the Lohammar equation (Lohammar et al., 1980) for calculating leaf conductance and surface resistance.	0.02	0.1	Results from a pre-study calibration with the site data
$g_{max, moss}$	ConductMax(2)	m^2 s^{-1}	2.10	Transpiration efficiency	Transpiration coefficient for mosses: the maximal conductance of fully open stomata in the Lohammar equation (Lohammar et al., 1980) for calculating leaf conductance and surface resistance.	0.017	0.03	Results from a pre-study calibration with the site data
g_{maxwin}	CondMaxWinter	m s^{-1}	2.10	Transpiration efficiency outside the growing season	Maximal conductance of fully open stomata to calculate the potential transpiration of plants during winter	0.001	0.03	Results from a pre-study calibration with the site data
t_{WA}	TempCoefA	-	2.13	Transpiration stress due to limited water availability under low temperatures	Temperature coefficient in the temperature response function.	0.8	10	Results from a pre-study calibration with the site data
ψ_c	CritThresholdDry	cm water	2.12	Transpiration stress due to too low water content	Critical pressure head for reduction of potential water uptake. A wide range (100-3000 cm water) of values has been reported in the literature. Lower values are expected for sandy soils with low root densities and higher values are expected for clayey soils with high root densities	1	330	Results from a pre-study calibration with the site data
p_1	DemandRelCoef	day^{-1}	2.12	Transpiration stress due to too low water content	Coefficient for the dependence of potential water uptake in the reduction function. The dependence of the potential uptake rate has frequently been reported as an important phenomenon for reduction of water uptake	0.3	2	0.3 (default value)
ψ_{eg}	EquilAdjustPsi	-	3.7	Vapour pressure at the soil surface	Factor to account for differences between water tension in the middle of top layer and actual vapour pressure at soil surface	0	2	1 (default value)
$c_{H0, canopy}$	WindLessExchangeCanopy	m s^{-1}	2.6	Aerodynamic resistance of canopy: minimum exchange under stabile conditions	Roughness length used in the calculation of r_a for each plant, corresponds to z_0 in Equation 2.6.	$1 \cdot 10^{-4}$	0.1	0.001 (default value)
$r_{a,max,snow-1}$	WindlessExChangeSnow	s^{-1}		Aerodynamic resistance of snow: minimum exchange under stabile conditions	Minimum turbulent exchange coefficient (inverse of maximum allowed aerodynamic resistance) over snow. Avoids exaggerated surface cooling in windless conditions or extreme stable stratification.	0	$1 \cdot 10^{-4}$	Results from a pre-study calibration with the site data

Symbol	Parameter Name	Unit	Equation (cf. Table S2)	Module	Definition	Min	Max	Literature or default value
r_{alai}	RaIncreaseWithLAI	s m^{-1}	3.5	Aerodynamic resistance: contribution of LAI	The contribution of LAI to the total aerodynamic resistance from measurement height (reference level) to the soil surface.	100	800	Results from a pre-study calibration with the site data
$z_{0M,snow}$	RoughLMomSnow	m	2.7, 2.8	Aerodynamic resistance: roughness length of snow	Roughness length for momentum above snow.	$1 \cdot 10^{-5}$	0.001	Results from a pre-study calibration with the site data
s_k	SThermalCondCoef	W m^5 $°C^{-1}$ kg^{-2}	4.1	Soil temperature: thermal conductivity of snow	Thermal conductivity coefficient for snow.	$1.2 \cdot 10^{-6}$	$2.86 \cdot 10^{-6}$	Results from a pre-study calibration with the site data
h_2	OrganicC2	-	6.3	Soil temperature – thermal conductivity	Empirical constant in the heat conductivity of the organic material at the surface	0.0045	0.0075	0.005 (default value)
T_{amean}	TempAirMean	°C	6.5	Soil temperature – lower boundary	Assumed value of mean air temperature for the lower boundary condition for heat conduction.	5.5	8	Based on results from a pre-study calibration with the site data. Should be 1.5-5°C higher than annual mean temperature (Metzger et al. 2015) which was 2.3 °C at Degerö during the simulation period
a_{pgrain}	AlbedoGrainStage(1)	%	2.1	Radiation interception: plant albedo	Plant albedo during grain stage	20	31	Dry grass and straw up to 29 and 33, respectively (Kondratiev et al., 1964)
$a_{pve, vasc}$	AlbedoVegStage(1)	%	2.1	Radiation interception: vascular plant albedo	Plant albedo of vascular plants during vegetative stage	10	25	12-22 for *Carex*; 12.5 for bog, raised edge; 17.8 for bog, depression (Petzold and Rencz, 1975)
$a_{pve, moss}$	AlbedoVegStage(2)	%	2.1	Radiation interception: moss albedo	Plant albedo of vascular plants during vegetative stage	10	30	11-16% in a *Sphagnum*-sedge bog (Berglund and Mace, 1972), 16.4 for *Sphagnum*, 17.5 for *Carex*, 17.9 for *Pragmites* (Zhao et al., 1997)
$\varepsilon_{L, vasc}$	RadEfficiency(1)	gDw MJ^{-1}	1.1	Plant assimilation efficiency	Radiation use efficiency of vascular plants for photosynthesis under optimum temperature, moisture and nutrients conditions	1.05	1.31	Based on results from a pre-study calibration with the site data. Ranges were selected in that way, that mosses and vascular plants can contribute approximately similar to photosynthesis during summer (Vermeij, 2013). Actual values differ due to the different plant coverage.
$\varepsilon_{L, moss}$	RadEfficiency(2)	gDw MJ^{-1}	1.1	Plant assimilation efficiency	Radiation use efficiency of mosses for photosynthesis under optimum temperature, moisture and nutrients conditions	0.1	0.2	Based on results from a pre-study calibration with the site data. Ranges were selected in that way, that mosses and vascular plants can contribute approximately similar to photosynthesis during summer (Vermeij, 2013). Actual values differ due to the different plant coverage.
$p_{mn, vasc}$	T LMin(1)	°C	1.2	Plant assimilation:	Minimum mean air temperature for	-6	5	-6 reported for some alpine plants (Körner,

Symbol	Parameter Name	Unit	Equation (cf. Table S2)	Module	Definition	Min	Max	Literature or default value
				temperature response	photosynthesis for vascular plants			1999), 5 (default value)
$p_{mn, moss}$	T LMin(2)	°C	1.2	Plant assimilation: temperature response	Minimum mean air temperature for photosynthesis for mosses	-6	5	-6 reported for some alpine plants (Körner, 1999), 5 (default value)
$p_{o1, vasc}$	T LOpt1(1)	°C	1.2	Plant assimilation: temperature response	Lower limit mean air temperature for optimum photosynthesis for vascular plants	8	14	Need to be higher than T LMin, but lower T LOpt2
$p_{o2, vasc}$	T LOpt2(1)	°C	1.2	Plant assimilation: temperature response	Upper limit mean air temperature for optimum photosynthesis for vascular plants	20	32	23-32° C for different *Poacea*-species (Wohlfahrt et al., 1999); 12-22 °C for *Carex* and *Eriophorum* (Kummerow and Ellis, 1984)
$p_{o1, moss}$	T LOpt1(2)	°C	1.2	Plant assimilation: temperature response	Lower limit mean air temperature for optimum photosynthesis for mosses	5	14	Need to be higher than T LMin, but lower T LOpt2
$p_{o2, moss}$	T LOpt2(2)	°C	1.2	Plant assimilation: temperature response	Upper limit mean air temperature for optimum photosynthesis for mosses	18	32	*Sphagnum*: 18 °C (Clymo and Hayward, 1982); depending on water content, at least 27 °C (Grace, 1973)
$f_{SnowReduceLAI}$	SnowReduceLAIThreshold			Plant LAI reduction due to snow cover	Minimum fraction of canopy above snow surface to allow transpiration or interception evaporation	$1\cdot10^{-3}$	0.01	Results from a pre-study calibration with the site data
l_{Lc1}	LeafRate1(1)	day^{-1}	1.10, 1.12	Plant litter fall: leaf litter fall rate during the season	Rate coefficient for the leaf litter fall before the first threshold temperature sum t_{L1} is reached	$2.5\cdot10^{-4}$	0.01	Results from a pre-study calibration with the site data
l_{LS}	C Leaf to Stem(1)	-	1.8,	Plant litter fall: rate for leaf yellowing at the end of the vegetation period	Scaling factor for reallocation of C from the photosynthetically active to the passive pool after the plant reached maturity growth state	0.02	0.03	Results from a pre-study calibration with the site data
$l_{Rc1, moss}$	RootRate1(2)		1.12	Plant litter fall		$2.5\cdot10^{-4}$	0.0025	Results from a pre-study calibration with the site data
$l_{Rc2, moss}$	RootRate2(2)		1.12	Plant litter fall		$2.5\cdot10^{-4}$	0.0025	Calibrated relative to l_{Rc1}
$T_{Mature Sum}$	Mature Tsum(1)	°C		Plant phenology: start of senescense	Temperature sum beginning from grain filling stage for plant reaching maturity stage	320	330	Metzger et al., 2015 found best values leading to grain filling start around mid to end of July, which corresponds to 320-330 at this site
$k_{gresp, moss}$	GrowthCoef(2)		1.6	Plant respiration		0.2	0.6	A wider range was selected for mosses compared to vascular plants, as due to the selected conceptual model, moss respiration was only growth depending, while there is an additional LAI depending component for vascular plants. Fraction of assimilates, lost by respiration according to Rice et al. 2008 for different Sphagnum species: 33-62%

Symbol	Parameter Name	Unit	Equation (cf. Table S2)	Module	Definition	Min	Max	Literature or default value
$k_{gresp, vasc}$	GrowthCoef(1)	day^{-1}	1.6	Plant respiration	Rate coefficient for growth respiration of the plant (respiration relative to amount of assimilates)	0.14	0.4	Results from a pre-study calibration with the site data
t_{Q10}	RespTemQ10	-	1.7	Plant respiration: temperature response	response to a 10 °C soil temperature change on plant maintenance respiration	1.8	3	Dark respiration in *Eriophorum*: 1.1-3.7 (van de Weg et al., 2013)
$p_{zroot, vasc}$	Root LowestDepth(1)	m	1.13	Plant rooting depth – important for water uptake and root litter input within the soil profile	Maximum root depth in the function for calculating the actual root depth	-0.5	-0.14	Estimated maximum rooting depth for this site is 30-45cm (Peichl, 2015, personal communication).
$p_{zroot, moss}$	Root LowestDepth(2)		1.13	Plant rooting depth – important for water uptake and root litter input within the soil profile	Maximum root depth in the function for calculating the actual root depth	-0.1	-0.01	Estimation
m_{retain}	Mobile Allo Coef(1)	-	1.14	Plant storage pool for regrowth in spring	Coefficient for determining ratio of leaf carbon, allocated to the mobile storage pool during leaf litter fall	0.2	0.6	0.01-0.4 was found in Metzger et al., 2015 for several peatland sites, however pre-study results suggested higher values for this site
k_{l1}	RateCoefLitter1	a^{-1}	5.1	SOC decomposition	Rate coefficient for the decay of SOC in the plant litter pools for mosses	$2\cdot10^{-4}$	0.02	1·10-5 to 0.03 by calibration (Metzger et al., 2015)
k_h	RateCoefHumus	day^{-1}	3.8	SOC decomposition	rate coefficient for the decay of C in the slow SOC pools	$1\cdot10^{-9}$	$2\cdot10^{-5}$	$1\cdot10^{-5}$ (default value)
t_{min}	TempMin	°C	5.3	SOC decomposition – temperature response	The temperature in the Ratkowsky function at which microbial activity is 0% .	-10	0	-8 (default value)
t_{max}	TempMax	°C	5.3	SOC decomposition – temperature response	The temperature in the Ratkowsky function at which the response on microbial activity is 100%.	20	30	20 (default value)
$p_{\theta Satact}$	SaturationActivity	vol %	5.4	SOC decomposition – water response	Parameter in the soil moisture response function defining the microbial activity under saturated conditions	$1\cdot10^{-6}$	0.01	A very low value was chosen to get a strong response to droughts.
$p_{\theta Low}$	ThetaLowerRange	vol %	5.4	SOC decomposition – water response	Water content interval in the soil moisture response function for microbial activity, mineralisation−immobilisation, nitrification and denitrification.	3	20	13 (default value)
$p_{\theta Upp}$	ThetaUpperRange	vol %	5.4	SOC decomposition – water response	Water content interval in the soil moisture response function for microbial activity	6	10	8 (default value)
k_{l2}	RateCoefLitter2	a^{-1}	5.1	SOC decomposition	Rate coefficient for the decay of SOC in the plant litter pools for vascular plants	$2\cdot10^{-5}$	0.002	Calibrated relative to k_{l1}

Table S2. List of main equations used in this study

Equation	No.	Definition
Plant biotic processes		
$C_{Atm \to a} = \varepsilon_L \cdot \eta \cdot f(T_l) \cdot f(E_{ta}/E_{tp}) \cdot R_{s,pl}$ where ε_L is the radiation use efficiency and η is the conversion factor from biomass to carbon. $R_{s,pl}$ is the global radiation absorbed by canopy and $f(T_l)$,and $f(E_{ta}/E_{tp})$ limitations due to unfavourable temperature, nitrogen, and water conditions.	(1.1)	Rate of photosynthesis (g C m^{-2} day^{-1})
$f(T_l) = \begin{cases} 0 & T_l < p_{mn} \\ (T_l - p_{mn})/(p_{o1} - p_{mn}) & p_{mn} \le T_l \le p_{o1} \\ 1 & p_{o1} < T_l < p_{o2} \\ 1-(T_l - p_{o2})/(p_{mx} - p_{o2}) & p_{o2} \le T_l \le p_{mx} \\ 0 & T_l > p_{mx} \end{cases}$ where p_{mn}, p_{o1}, p_{o2} and p_{mx} are parameters and T_l the leaf temperature.	(1.2)	Temperature response function for photosynthesis
$f(E_{ta}/E_{tp}) = \frac{E_{ta}}{E_{tp}}$ where E_{ta} (Eq. 29) and E_{tp} (Eq. 23) are actual and potential transpiration.	(1.3)	Response function for transpiration
$C_{a \to Leaf} = l_{cl} \cdot C_a$ where l_{cl}, is a parameter and C_a the new assimilated carbon.	(1.4)	Allocation of new assimilates to the leaves
$C_{a \to Root} = (1 - l_{cl}) \cdot C_a$ where l_{cl}, is a parameter and C_a the new assimilated carbon.	(1.5)	Allocation of new assimilates to the roots, respectively to below ground parts in case of mosses
$C_{respleaf} = k_{mrespleaf} \cdot f(T) \cdot C_{leaf} + k_{gresp} \cdot C_{a \to Leaf}$ where $k_{mrespleaf}$ is the maintenance respiration coefficient for leaves, k_{gresp} is the growth respiration coefficient, and $f(T_a)$ is the temperature. The equation calculates respiration from stem, roots, and grains by exchanging $k_{mrespleaf}$ to $k_{mrespstem}$, $k_{mresproot}$, $k_{mrespgrain}$, and using the corresponding storage pools. Respiration from the old carbon pools is estimated with the same maintenance respiration coefficients as for respiration from new carbon pools.	(1.6)	Plant growth and maintenance respiration (g C m^{-2} day^{-1})
$f(T) = t_{Q10}^{(T - t_{Q10bas})/10}$ where t_{Q10} and t_{Q10bas} are parameters.	(1.7)	Temperature response function for maintenance respiration (–)
$C_{Leaf \to Stem} = l_{LS} \cdot C_{Leaf}$ where l_{LS} is a parameter and C_{Leaf} the carbon in the leaf pool.	(1.8)	Reallocation of C from leaf pool to stem pool – here used as pool for senescent leaves.
$C_{Leaf \to LitterSurface} = f(T_{Sum}) \cdot f(A_l) \cdot s_{newleaf} \cdot C_{Leaf}$ where $s_{newleaf}$ is a scaling factor. Stem C is calculated analogously with $s_{newstem}$.	(1.9)	Leaf C entering the surface litter pool is depending on the temperature sum and leaf area index.
$f(l_{Lc}) = l_{Lc1} + (l_{Lc2} - l_{Lc1}) \cdot \min\left(1, \frac{\max(0, T_{Sum} - t_{L1})}{\max(1, t_{L2} - t_{L1})}\right)$	(1.10)	Leaf litter fall dependence of temperature sum

where t_{L1}, t_{L2}, l_{Lc1} and l_{Lc2} are parameters and T_{Sum} is the so called “dorming” temperature sum, $T_{DormSum}$. $T_{DormSum}$ is calculated at the end to the growing season when the air temperature is below the threshold temperature $T_{DormTth}$, as the accumulated difference between $T_{DormTth}$ and Ta. $T_{DormTth}$ is a parameter.

The stem litter rate is calculated analogously with the parameters t_{S1}, t_{S2}, l_{Sc1} and l_{Sc2}, the root litter rate with the parameters l_{Lc2} to t_{R1}, t_{R2}, l_{Rc1} and l_{Rc2}.

$$f(A_l) = e^{l_{LaiEnh}\cdot A_l}$$

(1.11) Litter fall dependency of LAI

where l_{LaiEnh} is a parameter and A_l the leaf area index

$$C_{Root\rightarrow Litter} = f(l_{Rc})\cdot C_{Root}\cdot s_{newroot}$$

(1.12) Root C entering the soil litter pool of the corresponding layer

where $s_{newroot}$ is a scaling factor. The root litter rate function, $f(l_{Rc})$, can be calculated with Eq. (10) by exchanging the parameters t_{L1}, t_{L2}, l_{Lc1} and l_{Lc2} to t_{R1}, t_{R2}, l_{Rc1} and l_{Rc2}.

$$z_r = p_{zroot}\left(\frac{B_r}{B_r+\frac{p_{zroot}}{p_{incroot}}}\right)$$

(1.13) Root depth

where p_{zroot} and $p_{incroot}$ are parameters and B_r is the mass of roots (i.e. the carbon content in the roots, C_{Roots} +$C_{OldRoots}$).

$$C_{Mobile} = (C_{Leaf\rightarrow LitterSurface}+C_{OldLeaf\rightarrow LitterSurface})\cdot m_{retain}$$

(1.14) Allocation to the mobile C pool for developing new leaves during litter fall

where m_{retain} is an allocation coefficient.

$$C_{RemainLeaf} = C_{OldLeaf}\,(1-\frac{1}{l_{life}-1})$$

(1.15) Fraction of the whole $C_{OldLeaf}$ pool that will be excluded from the calculation of the litterfall from the old leaves

where l_{life} is a parameter

$$C_{Mobile\rightarrow Leaf} = C_{Mobile}\cdot m_{shoot}$$

(1.16) Allocation from the mobile C pool at leafing (between GSI 1 and 2) as an additional supply. This process goes on as long as there is carbon left in the mobile pool.

where m_{shoot} is an allocation coefficient and C_{Mobile} the carbon in the mobile pool.

Plant abiotic processes

$$R_{s,pl} = (1-e^{-k_{rn}\frac{A_l}{f_{cc}}})\cdot f_{cc}\left(1-a_{pl}\right)R_{is}$$

(2.1) Plant interception of global radiation

(MJ m^{-2} day^{-1})

where k_{rn} is the light use extinction coefficient given as a single parameter common for all plants, f_{cc} is the surface canopy cover, a_{pl} is the plant albedo and R_{is}, is the global qion.

The plant albedo is calculated from the parameters: albedo vegetative stage, *apveg*, and/or albedo grain stage, *apgrain*, depending on plant development.

$$f_{cc} = p_{c\max}(1-e^{-p_{ck}A_l})$$

(2.2) Surface canopy cover (m^2 m^{-2})

Where p_{cmax} is a parameter that determines the maximum surface cover and p_{ck} is a parameter that governs the speed at which the maximum surface cover is reached. A_l is the leaf area index of the plant.

$$A_l = \frac{B_l}{p_{l,sp}}$$

(2.3) Leaf area index (m^2 m^{-2}) as function of leaf mass

Where $p_{l,sp}$ is a parameter and B_l is the total mass of leaf.

$$L_\upsilon E_{tp} = \frac{\Delta R_n + \rho_a c_p \dfrac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \dfrac{r_s}{r_a}\right)}$$

(2.5) Potential transpiration E_{tp} (mm day^{-1})

where R_n is net radiation available for transpiration, e_s is the vapour pressure at saturation, e_a is the actual vapour pressure, ρ_a is air density, c_p is the specific heat of air at constant pressure, L_v is the latent heat of vaporisation, Δ is the slope of saturated vapour pressure versus temperature curve, γ is the psychrometer ‘constant’, r_s is ‘effective’ surface resistance and r_a is the aerodynamic resistance.

$$r_a^* = \frac{\ln^2\left(\dfrac{z_{ref} - d}{z_0}\right)}{k^2 u} + \Delta z_{snow}$$

(2.6) The aerodynamic resistance r_a as calculated without stability correction

where the wind speed, u, is given at the reference height, z_{ref}, k is von Karman‘s constant, d is the displacement height and z_o is the roughness length.

$z_0 = z_{0max}$ $\qquad$ $z_0 > z_{0max}$

$z_0 = (H_p - \Delta z_{snow} \min(f_1, f_2)) + \Delta z_{snow}$ $\qquad$ $z_{0min} > z_0 > z_{0max}$

$z_0 = z_{0min}$ $\qquad$ $z_0 < z_{0min}$

(2.7) The roughness length, z_0, is calculated according to the function derived from Shaw and Pereira (1982)

where z_{0max} and z_{0min} are parameters, f_1 and f_2 are functions describing the dependency on leaf area index and canopy density, Δz_{snow} is the snow depth and H_p is the canopy height.

$$d = \min\left(\begin{matrix} z_{ref} - 0.5 \\ \left(\begin{matrix}(0.80 + 0.11 p_{densm}) - \\ (0.46 - 0.09 p_{densm}) e^{-(0.16 + 0.28 p_{densm})^{PAI}}\end{matrix}\right)(H_p - \Delta z_{snow})\end{matrix}\right) + \Delta z$$

(2.8) Displacement height d, as calculated by the Shaw and Pereira function

p_{densm} is density maximum of canopy in relation to the canopy height, Δz_{snow} is the snow depth. *PAI* is the plant area index, H_p is the canopy height.

$$r_s = \frac{1}{\max(A_l\, g_l, 0.001)}$$

(2.9) Stomatal resistance (s m^{-1})

where g_l is the leaf conductance and A_l the leaf area index.

$$g_l = \frac{R_{is}}{R_{is} + g_{ris}} \frac{g_{max}}{1 + \dfrac{(e_s - e_a)}{g_{vpd}}}$$

(2.10) Stomatal conductance per leaf area

(m s^{-1})

where g_{ris}, g_{max} and g_{vpd} are parameter values, g_{maxwin} corresponds to g_{vpd} in winter. R_{is}, is the global radiation and ($e_s - e_a$) the vapour pressure deficit.

$$E_{ta} = E_{tp}^* \int_{z_r}^{0} f\left(\psi(z)\right)\left(T(z)\right) r\left(z\right)$$

(2.11) Actual transpiration without flexibility of water transportation within the root system.

z_r is root depth (Eq. 16), $f\left(\psi(z)\right)$ and $f(T(z))$ are response functions for soil water potential, and soil temperature and $r(z)$ is the relative root density distribution which is exponentially decreasing from soil surface to the root depth.

$$f\left(\psi(z)\right)=\left(\frac{\psi_c}{\psi(z)}\right)^{p_1E_{tp}+p_2} \tag{2.12}$$

Transpiration response to water stress

where p_1, p_2 and ψ_c are parameters. If the soil water potential is reaching the wilting point, ψ_{wilt}, the uptake is assigned to be zero from that horizon.

$$f\left(T(z)\right)=1-e^{-t_{WA}\max(0,T(z)-T_{trig})^{t_{WB}}} \tag{2.13}$$

Transpiration response to temperature as proposed by Axelsson and Ågren (1976)

where t_{WA} and t_{WB} and the trigging temperature T_{triq} are parameters.

Surface Energy balance

$$R_{ns}=L_vE_s+H_s+q_h \tag{3.1}$$

The physically based approach, for calculating soil evaporation, originates from the idea of solving an energy balance equation for the soil surface. According to the law of conservation of energy the net radiation at the soil surface, R_{ns}, is assumed to be equal to the sum of latent heat flux, L_vE_s, sensible heat flux, H_s and heat flux to the soil, q_h. The three different heat fluxes are estimated by an iterative procedure where the soil surface temperature, T_s, is varied according to a given scheme until the equation is balanced

$$H_s=\rho_ac_p\frac{(T_s-T_a)}{r_{as}} \tag{3.2}$$

sensible heat flux, H_s

where air density, ρ_a and the specific heat of air at constant pressure, c_p are considered as physical constants, r_{as} is the aerodynamic resistance calculated as a function of wind and temperature gradients

$$r_{as}=r_{aa}+r_{ab} \tag{3.3}$$

Aerodynamic resistance above the soil surface, r_{as}, is calculated as a sum of two components

where r_{aa} is a function of wind speed and temperature gradients, which is corrected for atmospheric stability, and r_{ab} is an additional resistance representing the influence of the crop cover,

$$\frac{r_{aa}=\dfrac{1}{k^2u}\left\{\ln\left(\dfrac{z_{ref}-d}{z_{0M}}\right)-\psi_{\mathrm{M}}\left(\dfrac{z_{ref}-d}{L_O}\right)+\psi_{\mathrm{M}}\left(\dfrac{z_{0M}}{L_0}\right)\right\}\times}{\times\left\{\ln\left(\dfrac{z_{ref}-d}{z_{0H}}\right)-\psi_{\mathrm{H}}\left(\dfrac{z_{ref}-d}{L_O}\right)+\psi_H\left(\dfrac{z_{0H}}{L_0}\right)\right\}} \tag{3.4}$$

Stability function for aerodynamic resistance at neutral conditions

where u is the wind speed at the reference height, z_{ref}, d is the zero level displacement height (c.f. potential transpiration of plant), k is the von Karmans constant and z_{0M} and z_{0H} are the surface roughness lengths for momentum and heat respectively. If z_{0M} is exchanged to $z_{0M,snow}$ the equation can be used for snow surfaces. L_O is the Obukhov length and ψ_M and ψ_H are empirical stability functions for momentum and heat respectively.

Furthermore, an upper limit of the aerodynamic resistance in extreme stable conditions is set by the “windless exchange” coefficient, $r_{a,soil,max}{}^{-1}$

$$r_{ab} = r_{aLai} A_l$$

(3.5) Additional aerodynamic resistance representing the influence of the crop cover

where r_{alai} is an empirical parameter

$$L_v E_s = \frac{\rho_a c_p (e_{surf} - e_a)}{\gamma \cdot r_{as}}$$

(3.6) Sum of latent heat flux, $L_v E_s$

Where e_{surf} is the vapour pressure at the soil surface and e_a is the actual vapour pressure in the air.

$$e_{surf} = e_s\left(T_s\right) e^{\left(\frac{-\psi_l M_{water} g \cdot e_{corr}}{R(T_s + T_{abszero}}\right)}$$

(3.7) Vapour pressure at the soil surface

where R is the gas constant, M_{water} is the molar mass of water, g is the gravity constant and e_s is the vapour pressure at saturation.

The empirical correction factor, e_{corr}, depends on an empirical parameter ψ_{eg} and a calculated mass balance at the soil surface, δ_{surf}, which is allowed to vary between the parameters s_{def} and s_{excess} given in mm of water.

$$q_h = k_h \frac{(T_s - T_1)}{\frac{\Delta z_1}{2}} + L q_{v,s}$$

(3.8) Heat flux to the soil, q_h.

where k_h is the thermal conductivity of the top soil layer, Lv, as well as the psychrometer constant, γ, are considered as physical constants; $q_{v,s}$, is the vapor flow from the soil surface to the central point of the uppermost compartment

$$q_{v,s} = -d_{vapd} f_a D_0(T) \frac{c_{vl} - c_{vs})}{\frac{\Delta z}{2}}$$

(3.9) Vapor flow from the soil surface to the central point of the uppermost compartment

where d_{vapb} is the tortuosity given as an empirical parameter, D_0 is the diffusion coefficient for a given temperature, f_a is the fraction of air filled pores ($\theta_s - \theta_s$) and c_{vs} and c_{v1} are the concentrations of water vapour at the soil surface and at the middle of the uppermost compartment respectively.

Snow

$$k_{snow} = s_k \rho_{snow}^2$$

(4.1) Thermal conductivity of snow

where s_k is an empirical parameter.

$$\rho_{snow} = \frac{\rho_{prec} \Delta z_{prec} + \rho_{old} \Delta z_{old}}{\Delta z_{snow}}$$

(4.2) Density of snow is a weighted average of the old snow pack (i.e. the density of snow remaining from the previous day ρ_{old}) and precipitation density, ρ_{prec}

$$\rho_{prec} = \rho_{smin} + 181 \frac{(1 - Q_p)}{f_{liqmax}}$$

(4.3) Density of new-fallen snow as a function of air temperature, T_a

where ρ_{smin} is the density of new snow, Q_p is the thermal quality of precipitation and f_{liqmax} is a parameter that defines the maximum liquid water content of falling snow that is automatically put to 0.5.

$$Q_P = \begin{cases} \min\left(1, \left(1 - f_{liqmax}\right) + f_{liqmax}\dfrac{T_a - T_{RainL}}{T_{SnowL} - T_{RainL}}\right) & T_a \le T_{RainL} \\ 0 & T_a > T_{RainL} \end{cases}$$

(4.4) Thermal quality of precipitation (its fractional frozen water content)

where f_{liqmax} is a parameter that defines the maximum liquid water content of falling snow and is automatically put to 0.5. T_{RainL} and T_{SnowL} are the temperature range where precipitation is regarded as a mixture of ice and liquid water.

$$\rho_{old} = \rho_{smin} + s_{dl}\frac{S_{wl}}{S_{wlmax}} + s_{dw}S_{res}$$

(4.5) Density of the old snow pack increases with the relative amount of free water in the pack and with overburden pressure, i.e., with increasing water equivalent. Density also generally increases with age. The age dependency is accounted for by updating density as the maximum density of the previous time step

where s_{dl} and s_{dw} are parameters, S_{wlmax} is the retention capacity and S_{res} is the water equivalent of the snow.

$$\Delta z_{old} = \frac{S_{res}}{\rho_{old}}$$

(4.6) Depth of old snow pack

$$f_{bare} = \begin{cases} \dfrac{\Delta z_{snow}}{\Delta z_{\mathrm{cov}}} & \Delta z_{snow} < \Delta z_{\mathrm{cov}} \\ 0 & \Delta z_{snow} \ge \Delta z_{\mathrm{cov}} \end{cases}$$

(4.7) The fraction of snow free ground is used the estimate the average soil surface temperature, and the average surface albedo, during conditions of "patchy" snow cover.

where Δz_{cov} is a threshold parameter.

$$M = M_T T_a + M_R R_{is} + \frac{f_{qh}q_h(0)}{L_f}$$

(4.8) The fundamental part of the empirically based snow model is the melting- freezing function, which combines the mass and heat budgets. The amount of snow melt, M, is made up by a temperature function, M_T, a function accounting for influence of solar radiation, M_R, and the soil surface heat flow, $q_h(0)$:

where T_a is air temperature, R_{is} is global radiation, f_{qh} is a scaling coefficient and L_f is the latent heat of freezing. Melting will affect the whole snow pack, whereas refreezing will only affect a limited surface layer.

$$M_T = \begin{cases} m_T & T_a \ge 0 \\ \dfrac{m_T}{\Delta z_{snow} m_f} & T_a < 0 \end{cases}$$

(4.9) Refreezing efficiency is, inversely proportional to snow depth, □z_{snow}:

where T_a is air temperature and m_T And m_f are parameters.

$$M_R = m_{R\min}(1 + s_1(1 - e^{-s_2 s_{age}}))$$

(4.10) Global radiation dependence of snow melt

where m_{Rmin}, s_1 and s_2 are parameters.

Age of surface snow, s_{age}, is determined by the number of days since the last snowfall. To reduce the influence of mixed precipitation and minor showers, snowfall is counted in this context only for snow spells larger than a critical value, p_{samin}, and for precipitation with thermal quality, Q_p, above a threshold value

Soil carbon and nitrogen processes

$$C_{DecompL} = k_l \cdot f(T) \cdot f(\theta) \cdot C_{Litter}$$

(5.1) Decomposition of the SOC pools for plant litter (g C m^{-2} day^{-1})

Where k_l is a parameter and $f(T)$ and $f(\theta)$ are response functions for soil temperature and moisture in the certain layer.		
$C_{DecompH} = k_h \cdot f(T) \cdot f(\theta) \cdot C_{Humus}$ Where k_h is a parameter and $f(T)$ and $f(\theta)$ are response functions for soil temperature and moisture in the certain layer.	(5.2)	Decomposition of the SOC pools for more stable material (g C m^{-2} day^{-1})
$f(\mathrm{T}) = 1 \qquad T > t_{\max}$ $f(\mathrm{T}) = \left(\frac{T - t_{\min}}{t_{\max} - t_{\min}}\right)^2 \qquad t_{\min} < T < t_{\max}$ $f(\mathrm{T}) = 0 \qquad T < t_{\min}$ Where t_{min} and t_{max} are parameters and T the soil temperature in the certain layer.	(5.3)	Response function for soil temperature according Ratkowsky. (–)
$f(\theta) = \begin{cases} p_{\theta satact} & \theta = \theta_s \\ \min\left(\left(\frac{\theta_s - \theta}{p_{\theta Upp}}\right)^{p_{\theta p}} \left(1 - p_{\theta satact}\right) + p_{\theta satact}, \left(\frac{\theta - \theta_{wilt}}{p_{\theta Low}}\right)^{p_{\theta p}} \right) & \theta_{wilt} \le \theta \le \theta_s \\ 0 & \theta < \theta_{wilt} \end{cases}$ where $p_{\theta Upp}$, $p_{\theta Low}$, $p_{\theta Satact}$, and $p_{\theta p}$ are parameters and the variables, θ_s, θ_{wilt}, and θ, are the soil moisture content at saturation, the soil moisture content at the wilting point, and the actual soil moisture content, respectively.	(5.4)	Response function for soil moisture (–)
$C_{LitterSurface \to Litter1} = l_{l1} \cdot C_{LitterSurface}$ where l_{l1} is a parameter and $C_{LitterSurface}$ the carbon in the surface litter pool.	(5.5)	Litter from inactive surface litter pool, entering the fast SOC pool at a continuous rate.
$C_{Litter->CO_2} = (1 - f_{e,l}) \cdot C_{DecompL}$ where $f_{e,l}$ is a parameter	(5.6)	Amount of decomposition products from the fast SOC pools being released as CO_2
$C_{Litter->Humus} = f_{e,l} \cdot f_{\mathrm{h,l}} \cdot C_{DecompL}$ where $f_{e,l}$ and $f_{h,l}$ are parameters	(5.7)	Amount of decomposition products from the fast SOC pools entering the slow decomposition pools
$C_{Litter->Litter} = f_{e,l}(1 - f_{\mathrm{h,l}}) \cdot C_{DecompL}$ where $f_{e,l}$ and $f_{h,l}$ are parameters	(5.8)	Amount of decomposition products from the fast SOC pools being returned to the fast decomposition pools
$C_{Humus->CO_2} = f_{e,\mathrm{h}} \cdot C_{DecompL}$ where $f_{e,h}$ is a parameter	(5.9)	Amount of decomposition products from the slow SOC pools being released as CO_2
Soil heat processes		
$q_h = -k_h \frac{\partial T}{\partial z}$ where k_h is the conductivity, T is the soil temperature and z is depth.	(6.1)	Soil heat flux (J m^{-2} day^{-1})
$q_h(0) = k_{ho} \frac{(T_s - T_1)}{\Delta z / 2} + C_w\left(T_s\right) q_{\mathrm{in}} + L_v q_{vo}$	(6.2)	Upper boundary condition for soil heat flow (J m^{-2} day^{-1})

where k_{ho} is the conductivity of the organic material at the surface, T_s is the surface temperature, T_1 is the temperature in the uppermost soil layer, q_{in}, is the water infiltration rate, q_{vo} is the water vapour flow, and L_v is the latent heat.

$$k_{ho} = h_1 + h_2\theta$$

(6.3) Heat conductivity of the organic material at the surface

where h_1 and h_2 are empirical constants

$$T_{ss} = \frac{T_1 + aT_a}{1+a}$$

(6.4) Soil surface temperature under the snow pack, during periods with snow cover (°C)

where the index 1 means the top soil layer, and the snow surface temperature is assumed to be equal to air temperature. a is a weighting factor depending on snow thickness and conductivity in the snow pack and in the uppermost soil layer.

$$T_{LowB} = T_{amean} - T_{aamp}e^{-\frac{z}{d_a}}\cos\left(\left(t - t_{ph}\right)\omega - \frac{z}{d_a}\right)$$

(6.5) Temperature at the lower boundary for heat conduction (°C)

where T_{amean} and T_{aamp} are parameters, t is the time, t_{ph} is the phase shift, ω is the frequency of the cycle and d_a is the damping depth.

Soil water processes

$$q_w = -k_w\left(\frac{\partial\psi}{\partial z} - 1\right) - D_v\frac{\partial c_v}{\partial z}$$

(6.6) The total water flow, q_w, is the sum of the matrix flow, q_{mat} and the vapour flow, q_v, (mm day^{-1})

where k_w is the unsaturated hydraulic conductivity, ψ is the water tension, z is depth, c_v is the concentration of vapour in soil air and D_v is the diffusion coefficient for vapour in the soil

$$\frac{\partial\theta}{\partial t} = -\frac{\partial q_w}{\partial z} + s_w$$

(6.7) The general equation for unsaturated water flow follows from the law of mass conservation and eq. (30)

where θ is the soil water content and s_w is a source/sink term for e.g. horizontal in and outflow or root water uptake.

$$S_e = \left(\frac{\psi}{\psi_a}\right)^{-\lambda}$$

(6.8) Water tension ψ according to Brooks and Corey (1965), between the threshold values ψ_x and $\psi_{mat.}$

where ψ_a is the air-entry tension, λ is the pore size distribution index and S_e the effective saturation.

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}$$

(6.9) Effective saturation $S_{e,}$ between the threshold values ψ_x and $\psi_{mat.}$

where θ_s is the porosity, θ_r is porosity content and θ is the actual water content.

$$k_w^* = k_{mat}\left(\frac{\psi_a}{\psi}\right)^{2+(2+n)\lambda}$$

(6.10) Unsaturated hydraulic conductivity k_w^* (mm day^{-1}) according Brooks and Corey.

Where the matrix conductivity k_{mat} is a function of the total conductivity, n is a parameter accounting for pore correlation and flow path tortuosity and λ is the pore size distribution index.

$$k_{mat} = 10^{(\log k_{sat} - \log h_{com})h_{sens} + \log k_{sat}}$$

(6.11) Matrix conductivity as function of total conductivity

where h_{com} and h_{sens} are parameters and k_{sat} is the total saturated conductivity.

$$q_{wp} = \int_{z_p}^{z_{sat}} k_s \frac{\left(z_{sat} - z_p\right)}{d_u d_p} dz$$

(6.12) The horizontal flow rate, q_{wp}, is assumed to be proportional to the hydraulic gradient and to the thickness and saturated hydraulic conductivity of each soil layer

where d_u is the unit length of the horizontal element i.e. 1 m, z_p is the lower depth of the drainage pipe i.e. the drainage level, z_{sat} is the simulated depth of the ground water table and d_p is a characteristic distance between drainage pipes. Note that this is a simplification where the actual flow paths and the actual gradients are not represented. Only flows above the drain level z_p are considered

$$k_w^* = 10^{\left(\log(k_w^*(\theta_s - \theta_m)) + \frac{\theta + \theta_s + \theta_m}{\theta_m} \log\left(\frac{k_{sat}}{k_w(\theta_s - \theta_m)}\right)\right)}$$

(6.13) Total conductivity close to saturation (above the threshold ψ_x), to account for the conductivity in the macro pores.

where k_{sat} is the saturated total conductivity, which includes the macro pores, and k_w*(θ_s - θ_m) is the hydraulic conductivity below θ_s - θ_m (i.e. at ψ_{mat}) calculated from Eq. (51)

$$k_w = (r_{AOT} + r_{A1T} T_s) \max(k_w^*, k_{minuc})$$

(6.14) Actual unsaturated hydralic conductivity after temperature corrections

where r_{AOT}, r_{A1T} and k_{minuc} are parameter values. k_w* is the conductivity according to eqs (51) and (52)

Table S3. Fixed parameters used in the main equations.

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
η	Biomass to carbon	mol C g^{-1} dw	1.1	Plant biomass:C ratio	Conversion factor from biomass to carbon	0.45	Default value
p_{mx}	PhoTempResMax	°C	1.2	Plant assimilation: temperature response	Maximum mean air temperature for photosynthesis	45	Based on results from a pre-study calibration with the site data.
l_{cl}	Leaf c1(1)	g C^{-1}	1.4, 1.5	Plant allocation of assimilates to the leaves	Fraction of new assimilates which is allocated to the leaves	0.545	Metzger et al., 2015
$k_{mrespleaf, vasc}$	MCoefLeaf(1)	day^{-1}	1.6	Plant respiration	Rate coefficient for maintenance respiration of vascular plant leaves (respiration relative to leaf biomass)	0.0025	Based on results from a pre-study calibration with the site data.
$k_{mresproot, vasc}$	MCoefRoot(1)	day^{-1}	1.6	Plant respiration	Maintenance respiration coefficient for vascular plant root (respiration relative to root biomass)	0.0025	Metzger et al., 2015
$k_{mrespstem, moss}$	MCoefStem(1)	day^{-1}	1.6	Plant respiration	Maintenance respiration coefficient for vascular plant stem = photosynthetically inactive biomass like e.g. senescent leaves that are still attached to the plant (respiration relative to stem biomass)	0	No respiration, as this represents brown, senescent biomass
$k_{mrespleaf, moss}$	MCoefLeaf(2)	day^{-1}	1.6	Plant respiration	Rate coefficient for maintenance respiration of moss leaves (respiration relative to leaf biomass)	0	No leaf respiration for mosses to allow a fixed moss capita
$k_{mresproot, moss}$	MCoefRoot(2)	day^{-1}	1.6	Plant respiration	Maintenance respiration coefficient for moss "root" = leaves and stem below the capita (respiration relative to root biomass)	0.0025	Based on results from a pre-study calibration with the site data.
t_{Q10bas}	TemQ10Bas	°C	1.7	Plant respiration: Temperature response	Base temperature for the temperature response of plant respriation, at which the response is 1	20	Default value
$s_{newstem}$	New Stem(1)	-		Plant litter fall	Scaling factor for litter fall from new stems	1	Full litterfall rate applies, no scaling
l_{Sc1}	StemRate1(1)	day^{-1}	1.10	Plant litter fall	Rate coefficient for the litter fall from stems before the first threshold temperature sum t_{S1} is reached	0.05	Based on results from a pre-study calibration with the site data.
l_{Sc2}	StemRate2(1)	day^{-1}	1.10	Plant litter fall	Rate coefficient for the litter fall from stems after the second threshold temperature sum t_{S2} is reached	0.5	Based on results from a pre-study calibration with the site data.
$s_{newleaf}$	New Leaf	-		Plant litter fall	Scaling factor for litter fall from new leaves	1	Full litterfall rate applies, no scaling
l_{Lc2}	LeafRate2(1)	day^{-1}	1.10	Plant litter fall: leaf litter fall rate at the end of the season	Rate coefficient for the leaf litter fall after the second threshold temperature sum t_{L2} is reached	0.5	Based on results from a pre-study calibration with the site data.
t_{L1}	LeafTsum1(1)	day°C	1.10	Plant litter fall	Threshold temperature sum after reaching dormancy state for the lower leaf litter rate. When it is reached, l_{Lc1} starts to change towards the increased litter fall rate l_{Lc2}	2	Based on results from a pre-study calibration with the site data.
t_{L2}	LeafTsum2(1)	day°C	1.10	Plant litter fall	Threshold temperature sum after reaching dormancy state for the higher leaf litter rate. When it is reached, the full high litter rate is applied.	14	Based on results from a pre-study calibration with the site data.
t_{S1}	StemTsum1(1)	day°C	1.10	Plant litter fall	Threshold temperature sum after reaching dormancy state for the lower stem litter rate. When it is reached, t_{Sc1} starts to change	2	Based on results from a pre-study calibration with the site data.

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
					towards the increased litter fall rate t_{Sc2}		
t_{L2}	StemTsum2(1)	day°C	1.10	Plant litter fall	Threshold temperature sum after reaching dormancy state for the higher stem litter rate. When it is reached, the full high litter rate is applied.	14	Based on results from a pre-study calibration with the site data.
$T_{DormTth}$	Dormancy Tth	°C	1.10	Plant litter fall	Threshold temperature for plant dormancy – if the temperature falls below this value for five consecutive days, the dormancy temperature sum starts to be calculated.	0.7	Based on results from a pre-study calibration with the site data.
l_{LaiEnh}	LAI Enh Coef(1)	-	1.11	Plant litter fall	Scaling factor for enhanced leaf litter fall rates when higher LAI values are reached	0.56	Metzger et al., 2015
t_{R1}	RootTsum1(1)	day°C	1.10, 1.12	Plant litter fall	Threshold temperature sum after reaching dormancy state for the lower root litter rate. When it is reached, t_{Rc1} starts to change towards the increased litter fall rate t_{Rc2}	2	Based on results from a pre-study calibration with the site data.
t_{R2}	RootTsum2(1)	day°C	1.10, 1.12	Plant litter fall	Threshold temperature sum after reaching dormancy state for the higher root litter rate. When it is reached, the full high litter rate is applied.	14	Based on results from a pre-study calibration with the site data.
$s_{newroots}$	New Roots	-		Plant litter fall	Scaling factor for litter fall from new roots	1	Full litterfall rate applies, no scaling
$l_{Rc1, vasc}$	RootRate1(1)	day^{-1}	1.12	Plant litter fall	Rate coefficient for the litter fall from roots before the first threshold temperature sum t_{R1} is reached	0.00125	Based on results from a pre-study calibration with the site data.
$l_{Rc2, vasc}$	RootRate2(1)	day^{-1}	1.12	Plant litter fall	Rate coefficient for the litter fall from roots after the second threshold temperature sum t_{R2} is reached	0.005	Based on results from a pre-study calibration with the site data.
$l_{Rc1, moss}$	RootRate1(2)	day^{-1}	1.12	Plant litter fall	Rate coefficient for the litter fall from moss "roots" (=belowground leaves & stems) before the first threshold temperature sum t_{R1} is reached	0.0005	Based on results from a pre-study calibration with the site data.
$l_{Rc2, moss}$	RootRate2(2)	day^{-1}	1.12	Plant litter fall	Rate coefficient for the litter fall from moss "roots" after the second threshold temperature sum t_{R2} is reached	0.0005	Based on results from a pre-study calibration with the site data.
$l_{life, vasc}$	Max Leaf Lifetime	a	1.15	Plant litter fall	Maximum leaf lifetime vascular plant	1	Vascular plant leaves were assumed to be renewed after one year
$l_{life, vasc}$	Max Leaf Lifetime	a	1.15	Plant litter fall	Maximum leaf lifetime mosses	300	Moss capita was assumed to be constant and therefore never dies
	I C Leaf(1)	g m^{-2}			Initial N content of vascular plant leaves; defines C and therefore biomass by defined C:N ratio	32.5	Based on results from a pre-study calibration with the site data.
	I C Leaf(2)	g m^{-2}			Initial N content of moss leaves; defines C and therefore biomass by defined C:N ratio	95	Based on results from a pre-study calibration with the site data.
	I C Roots(1)	g m^{-2}			Initial N content of vascular plant roots defines C and therefore biomass by defined C:N ratio	100	Based on results from a pre-study calibration with the site data.
	I C Roots(2)	g m^{-2}			Initial N content of belowground moss parts ("roots") defines C and therefore biomass by defined C:N ratio	95	Based on results from a pre-study calibration with the site data.
$p_{incroot}$	Root IncDepth	-	1.13	Plants: shape of root distribution – important for water uptake and root litter input within the soil	Distribution parameter in the function for calculating the actual root depth	-1	Default value

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
				profile			
m_{shoot}	Shoot Coef	-	1.16	Plant storage pool for regrowth in spring	Coefficient for the rate at which C is reallocated from the mobile pool to the leaf at leafing	0.07	Based on results from a pre-study calibration with the site data.
k_{rn}	RntLAI	-	2.1	Plant radiation interception: partitioning between plants and soil	Extinction coefficient in the Beer's law used to calculate the partitioning of net radiation between canopy and soil surface	0.8	Based on results from a pre-study calibration with the site data.
$p_{cmax, vasc}$	Maximal Cover(1)	m^2 m^{-2}	2.2	Radiation interception: Plant coverage	Maximum surface cover of vascular plants	0.6	Visually estimated plant coverage at the site
$p_{cmax, moss}$	Maximal Cover(2)	m^2 m^{-2}	2.2	Radiation interception: Plant coverage	Maximum surface cover of mosses	1	Visually estimated plant coverage at the site
p_{ck}	Area kExp(1)	-	2.2	Radiation interception: Plant coverage	Speed at which the maximum surface cover of the plant canopy is reached	1	Based on results from a pre-study calibration with the site data.
$p_{l,sp}$	Specific LeafArea	g C m^{-2}	2.3	Plant LAI:phytomass ratio	Factor for calculating LAI from leaf biomass, which is actually the inverse of specific leaf area, i.e. leaf mass per unit leaf	47.5	Metzger et al., 2015
$T_{EmergeTh}$	TempSumCrit	°C		Plant phenology: start of growing season	Critical air temperature that must be exceeded for temperature sum calculation	5	Default value
$T_{EmergeSum}$	TempSumStart	°C		Plant phenology: start of growing season	Air temperature sum which is the threshold for start of plant development	50	Default value
$p_{densm, vasc}$	Canopy DensMax(1)	-	2.8	Plant: density of vascular plant canopy	The density maximum of canopy in relation to the canopy height	0.7	Default value
$p_{densm, moss}$	Canopy DensMax(2)	-	2.8	Plant: density of moss canopy	The density maximum of canopy in relation to the canopy height	0.9	Estimation for the site
g_{ris}	CondRis	J m^{-2} day^{-1}	2.10	Plant assimilation: radiation saturation	Global radiation intensity that represents half-light saturation in the light response	$5 \cdot 10^6$	Default value
$c_{H0, canopy}$	WindLessExchange Canopy	m s^{-1}	2.6	Aerodynamic resistance of canopy: minimum exchange under stabile conditions	Roughness length used in the calculation of ra for each plant, corresponds to *z0* in eq. 2.6.	0.001	Default value
z_{ref}	ReferenceHeight	m	2.6	Aerodynamic resistance of canopy: minimum exchange under stabile conditions	Height above ground which represent the level for measured air temperature, air humidity and wind speed.	2	Default value
z_{0max}	Roughness Max	m	2.7	Aerodynamic resistance: roughness length of plants	The maximum roughness length used when estimating roughness length of different canopies (see "Aerodynamic resistance").	3	Default value
z_{0min}	Roughness Min	m	2.7	Aerodynamic resistance: roughness length of plants	The minimum roughness length used when estimating roughness length of different canopies	0.01	Default value
g_{vpd}	CondVPD	Pa	2.10	Transpiration stress due to low air humidity	Vapour pressure deficit that corresponds to a 51 % reduction of stomata conductance	100	Default value
p_2	NonDemandRelCoef	kg m^{-2} day^{-1}	27	Transpiration stress due to too low water content	Coefficient in moisture reduction function. The degree of reduction when the actual pressure head exceeds the critical threshold, ψ_c, is controlled by this coefficient together with *p1* and the potential transpiration rate, *Etp*.	0.1	Default value
p_{ox}	AirRedCoef	-	28	Transpiration and assimilation stress due to high	A rate coefficient that governs how rapidly the plant resistance will increase because of the lack of	0	The plants are assumed to be well adapted to wet conditions and therefore

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
				water content	oxygen when the water content of the soil exceeds the value give by the actual soil moisture content, θ		do not suffer from water stress due to too wet conditions
θ_{Amin}	AirMinContent	vol %	29	Transpiration and assimilation stress due to high water content	The minimum amount of air that is necessary to prevent any reduced uptake of water from the soil	0	The plants are assumed to be well adapted to wet conditions and therefore do not suffer from water stress due to too wet conditions
t_{WB}	TempCoefB	-	2.13	Transpiration stress due to limited water availability under low temperatures	Temperature coefficient in the temperature response function.	0.4	Default value
t_{WC}	TempCoefC	-		Transpiration stress due to limited water availability under low temperatures	Temperature coefficient governing the trigging temperature.	0	Default value
$r_{a,soil,max}^{-1}$	WindLessExchangeSoil	-	3.4	Aerodynamic resistance: upper limit under windless conditions	Minimum turbulent exchange coefficient (inverse of maximum allowed aerodynamic resistance) over bare soil. Avoids exaggerated surface cooling in windless conditions or extreme stable stratification.	0.001	Default value
z_{0M}	RoughLBareSoilMom	m	3.4	Aerodynamic resistance: roughness length of bare soil	Surface roughness length for momentum above bare soil.	0.001	Default value
s_{excess}	MaxSurfExcess	mm	3.7	Vapour pressure at the soil surface	The highest value allowed for the δ_{surf} variable, which is used in the calculations of soil surface resistance and vapour pressure at the soil surface.	1	Default value
s_{def}	MaxSurfDeficit	mm	3.7	Vapour pressure at the soil surface	The lowest value allowed for the δ_{surf} variable, which is used in the calculations of soil surface resistance and vapour pressure at the soil surface.	-2	Default value
d_{vapb}	DVapTortuosity	-	3.9		Correction factor because of non-perfect condition for diffusion	0.66	Default value
k~~$_{mat}$~~	Matrix Conductivity	mm day~~$^{-1}$~~	6.10	Soil hydraulic conductivity: temperature dependence	Saturated matrix conductivity	100	Default value
θ_s	Saturation	vol %	5.4, 6.9	Soil hydraulic properties: shape of water retention	Water content at saturation	98 (95)	Received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin, 2001) under consideration of the range for the calibrated parameter AirEntry; the value in brackets is used for layers below −30cm
θ_{wilt}	Wilting Point	vol %	5.4	Soil hydraulic properties: shape of water retention	Water content at wilting point	30 (30)	Received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin 2001) under consideration of the range for the calibrated parameter AirEntry; the value in brackets is used for layers below −30cm
ψ_x	Upper Boundary	cm	6.8, 6.9, 6.13	Soil hydraulic properties: shape of water retention	Soil water tension at the upper boundary of Brooks and Corey's expression	8000	Default value

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
λ	Lambda	-	6.8, 6.10	Soil hydraulic properties: shape of water retention	Pore size distribution index	0.3 (0.2)	Received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin 2001) under consideration of the range for the calibrated parameter AirEntry; the value in brackets is used for layers below −30cm
z	LowerDepth	m		Soil hydraulic properties: Border between horizons	Depth of the border between the upper and lower horizon in respect to hydrological properties	0.3	Boundary between acrotelm and catotelm, based on visual differences in the soil profile and water table depth measurements (Granberg et al., 1999).
h_1	OrganicC1	-	6.3	Soil temperature – thermal conductivity	Empirical constant in the heat conductivity of the organic material at the surface	0.06	Default value
T_{aamp}	TempAirAmpl	°C	6.5	Soil temperature – lower boundary	Assumed value of the amplitude of the sine curve , representing the lower boundary condition for heat conduction	10	Default value
Δz_{humus}	OrganicLayerThick	m		Soil thermal properties	Thickness of the humus layer as used as a thermal property	3	Site specific value for peat depth. Measurements at the site indicate a peat depth of 3-4m
θ_r	Residual Water	vol %	6.9	Soil hydraulic properties: shape of water retention	Residual soil water content	1 (1)	Received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin 2001) under consideration of the range for the calibrated parameter AirEntry; The value in brackets is used for layers below −30cm
n	n Tortuosity	-	6.10	Unsaturated soil hydraulic conductivity of soil	Parameter for pore correlation and flow path tortuosity in the function for unsaturated hydraulic conductivity	1 (1)	Based on results from a pre-study calibration with the site data. The value in brackets is used for layers below −30cm
z_p	DrainLevel	m	6.12	Soil water: drainage depth	Lower depth of the drainage	-0.12	Measured water level during wet periods at the site
	DrainLevelMin	m		Soil water: minimum drain level	Lowest possible water level	-0.6	Well below the lowest measured water table at that site (0.4).
θ_m	Macro Pore	vol %	6.13	Soil hydraulic properties: shape of water retention	Macro pore volume	4 (4)	Received by comparing resulting pF curves with curves measured in peatlands (Kellner and Lundin 2001) under consideration of the range for the calibrated parameter AirEntry; the value in brackets is used for layers below −30cm
k_{sat}	Total Conductivity	mm day^{-1}	6.11, 6.13	Saturated soil hydraulic conductivity of soil	Total conductivity under saturated conditions	1610 (800)	From measured dry bulk density according Päivänen, 1973
r_{A1T}	TempFacLinIncrease	°C^{-1}	6.14	Soil hydraulic conductivity: temperature dependence	The slope coefficient in a linear temperature dependence function for the hydraulic conductivity	0.023	Default value
r_{A0T}	TempFacAtZero	-	6.14	Soil hydraulic conductivity: temperature dependence	Relative hydraulic conductivity at 0°C compared with a reference temperature of 20°C.	0.55	Default value

Symbol	Parameter Name	Unit	Eq.	Module	Definition	Value	Literature or default value
k_{minuc}	MinimumCondValue	mm day^{-1}	6.14	Soil hydraulic conductivity	The minimum hydraulic conductivity in the hydraulic conductivity function.	$1 \cdot 10^{-5}$	Default value
$f_{e,l}$	Eff Litter1&2	day^{-1}	5.6, 5.7, 5.8	SOC decomposition	Fraction of decomposition products from the fast SOC pools being released as CO_2	0.5	Default value
$f_{h,l}$	HumFracLitter1&2	day^{-1}	5.6, 5.7, 5.8	SOC decomposition	Fraction of decomposition products from the fast SOC pools that will enter the slow decomposition pools	0.2	Default value
$p_{\theta p}$	ThetaPowerCoef	vol %	5.4	SOC decomposition – water response	Power coefficient in the response function of microbial activity in dependency of soil moisture	1	Default value
l_{l1}	RateCoefSurf L1&2	day^{-1}	5.5	SOC decomposition	Fraction of the above ground residues that enter the pool for fast decomposition of the uppermost soil layer	0.005	Default value
$f_{e,h}$	Eff Humus	day^{-1}	5.9	SOC decomposition	Fraction of decomposition products from the slow SOC pools being released as CO_2	0.5	Default value
cn_m	CN Ratio Microbe	-		SOC decomposition	Litter quality at which decomposers shift from immobilisation of mineral N to net mineralisation	30	Based on results from a pre-study calibration with the site data.
	Latitude	-			Geographic position; used for the calculation of cloudiness	65.18	Location of the site

Table S4. Correlation coefficients between parameters and performance. The maximum value is shown if a parameter correlated with several performance indices or several sub periods of the same variable. The first two digits after decimal point are displayed. Values < 0.14 are not shown.

Module	Symbol	NEE night dynamics	NEE night ME	LAI dynamics	LAI ME	NEE day dynamics	NEE day ME	NEE dynamics	NEE ME	Rad dynamics	Rad ME	Ts$_1$ dynamics	Ts$_1$ ME	Ts$_2$ dynamics	Ts$_2$ ME	H dynamics	H ME	LE dynamics	LE ME	WT dynamics	WT ME	Snow dynamics	Snow ME
SOC decomposition	$p_{\theta Upp}$																						
	$p_{\theta Low}$																						
	$p_{\theta Satact}$																						
	t_{max}																						
	t_{min}	23							32														
	k_h																						
	k_{l1}	33	31			30	30	70	33														
Plant	m_{retain}							30										32	30	31		21	
	$p_{zroot, moss}$																						
	$p_{zroot, vasc}$																						
	t_{Q10}																						
	$k_{gresp, vasc}$	52		60		55	28	30						28			21		31	45			
	$k_{gresp, moss}$	31	30						23														
	$T_{MatureSum}$																						
	$l_{Rc1, moss}$																						
	l_{LS}																						
	l_{Lc1}	30		86	33	32	49	44	30							32	29	50	28	68	13		
	$f_{SnowReduceLAI}$																						
	$p_{o2, moss}$																						
	$p_{o2, vasc}$																						
	$p_{o1, vasc}$																						
	$p_{mn, moss}$																						
	$p_{mn, vasc}$							33															
	$p_{o1, moss}$																						
	$\varepsilon_{L, moss}$						70		32														
	$\varepsilon_{L, vasc}$			51																			
Rn interc eptin	$a_{pve, vasc}$																						
	$a_{pve, vasc}$									77	76		52			63	62						
	a_{pgrain}																						
Soil tempe rature	T_{amean}														59								
	h_2											31	30	78	57								
	s_k					20				31		64	54	62	18					25			
Aerodyna mic resistance	$z_{0M,snow}$									31	67					54	58	72					
	r_{alai}	32										75	77	83	51			30	28	33	25		
	$r_{a,max,snow-1}$																						
	$c_{H0, canopy}$									32						56		86		20			
Transpiration	ψ_{eg}																						
	p_1																						
	ψ_c																						
	t_{WA}																						
	g_{maxwin}															17	61	72	75	51	32		
	$g_{max, moss}$							28				13				45	29	67	59	65	32		
	$g_{max, vasc}$	32																49	27	44	27		
Soil hydrol goy	d_p																			13	22		
	ψ_a	66	44		47	52	45	56		50		67		65		64	62	66	77	76	65	30	
	h_{com}																						
Snow	T_{RainL}															23						19	
	m_T											47	17			86				25		78	66
	ρ_{smin}											30	32	23								47	
	s_{dl}																					62	
	S_{dw}											21										61	58
	f_{qh}																						
	m_{Rmin}												21										
	Δz_{cov}																						

Table S5. Prior and posterior parameter ranges of the basic selection. Deviations of parameter ranges from the prior, after applying the basic criteria. Only parameters with a deviation are shown. The deviation is given in percentage of the prior range.

	Max	ψ_a	$k_{gresp,vasc}$	m_{retain}	$\varepsilon_{L,vasc}$	$g_{max,moss}$	l_{Lc1}	l_{LS}
Min Range deviation	3%	3%	0%	0%	0%	0%	0%	0%
Max Range deviation	1%	1%	0%	0%	0%	0%	0%	0%
Mean Range deviation	13%	8%	13%	8%	10%	8%	9%	7%
St.D range deviation	11%	11%	5%	4%	2%	2%	5%	1%
5 Percentile range deviation	11%	11%	2%	10%	4%	1%	0%	2%
51 Percentile range deviation	17%	10%	17%	10%	12%	10%	9%	10%
95 Percentile range deviation	19%	19%	14%	1%	1%	4%	13%	2%

Table S6. Correlation coefficients of the detected equifinalities. The first two digits after decimal point are displayed. Values < 0.14 are not shown.

	k_h	$p_{\theta Satact}$	t_{max}	t_{min}	$p_{\theta Low}$	$p_{\theta Upp}$	k_{l1}	$p_{zroot, vasc}$	$T_{MatureSum}$	$k_{gresp, vasc}$	$p_{mn, vasc}$	$p_{o1, vasc}$	$p_{o2, vasc}$	m_{retain}	$\varepsilon_{L, vasc}$	$\varepsilon_{L, moss}$	$p_{mn, moss}$	$p_{o1, moss}$	$p_{o2, moss}$	$k_{gresp, moss}$	$p_{zroot, moss}$	$l_{Rc1, moss}$	$f_{SnowReduceLAI}$	t_{Q10}	l_{Lc1}	l_{LS}	$a_{pve, vasc}$
$p_{\theta Upp}$																						16					
$p_{\theta Low}$																		16							21		
$p_{\theta Satact}$																				16							
t_{max}									18										21					18			
t_{min}																											19
k_h																											
k_{l1}																				19							
m_{retain}										20					19									17			
$p_{zroot, moss}$															19												
$p_{zroot, vasc}$																											
t_{Q10}			18											17			26					19					
$k_{gresp, vasc}$														20	25												
$k_{gresp, moss}$		16					19																				
$T_{MatureSum}$			18																								
$l_{Rc1, moss}$						16																		19			
l_{LS}																16											
l_{Lc1}					21																						
$f_{SnowReduceLAI}$												19															
$p_{o2, moss}$			21													19											
$p_{o2, vasc}$																											
$p_{o1, vasc}$																							19				
$p_{mn, moss}$																								26			
$p_{mn, vasc}$																24											
$p_{o1, moss}$					16																						
$\varepsilon_{L, moss}$											24								19							16	
$\varepsilon_{L, vasc}$										25				19							19						
$a_{pve, vasc}$				19																							
$a_{pve, vasc}$																											
a_{pgrain}																											
T_{amean}	14																										
h_2									20																		
s_k																							23				
$z_{0M,snow}$																											
r_{alai}																											
$r_{a,max,snow-1}$						16																					
$c_{H0, canopy}$									16	19										16							
ψ_{eg}																											
p_1												19												16			
ψ_c																											
t_{WA}																											
g_{maxwin}													17												20		
$g_{max, moss}$									21												20						
$g_{max, vasc}$																										22	
d_p		16							23		18																
ψ_a		17																									
h_{com}																											
T_{RainL}																											
m_T																										14	
ρ_{smin}					14																						
s_{dl}																											
S_{dw}							20				17																
f_{qh}	16																28	17									
m_{Rmin}																											
Δz_{cov}																											
Count	**2**	**3**	**3**	**1**	**3**	**2**	**2**	**0**	**5**	**3**	**3**	**2**	**1**	**3**	**3**	**3**	**2**	**2**	**2**	**3**	**2**	**2**	**2**	**5**	**2**	**3**	**1**

Table S6 continued.

	a_{pgrain}	$a_{pve, vasc}$	h_2	s_k	$z_{0M,snow}$	r_{alai}	T_{amean}	$r_{a,max,snow-1}$	$c_{H0, canopy}$	$g_{max, vasc}$	ψ_c	p_1	$g_{max, moss}$	ψ_{eg}	g_{maxwin}	t_{WA}	ψ_a	d_p	h_{com}	m_T	T_{RainL}	m_{Rmin}	f_{qh}	Δz_{cov}	ρ_{smin}	s_{dl}	S_{dw}
$p_{\theta Upp}$								16																			
$p_{\theta Low}$																									14		
$p_{\theta Satact}$																	17	16									
t_{max}																											
t_{min}																											
k_h							14																16				
k_{l1}																											20
m_{retain}																											
$p_{zroot, moss}$													20														
$p_{zroot, vasc}$																											
t_{Q10}												16															
$k_{gresp, vasc}$									19																		
$k_{gresp, moss}$									16																		
$T_{MatureSum}$			20						16				21					23									
$l_{Rc1, moss}$																											
l_{LS}										22										14							
l_{Lc1}															20												
$f_{SnowReduceLAI}$				23																							
$p_{o2, moss}$																											
$p_{o2, vasc}$															17												
$p_{o1, vasc}$												19															
$p_{mn, moss}$																							28				
$p_{mn, vasc}$																		18									17
$p_{o1, moss}$																							17				
$\varepsilon_{L, moss}$																											
$\varepsilon_{L, vasc}$																											
$a_{pve, vasc}$																											
$a_{pve, vasc}$					32	30			18																		
a_{pgrain}																		16									
T_{amean}																										21	
h_2													19				20										
s_k											19																
$z_{0M,snow}$		32																									
r_{alai}		30															18										
$r_{a,max,snow-1}$																											
$c_{H0, canopy}$		18															30										
ψ_{eg}																											
p_1																											
ψ_c				19																							
t_{WA}																			17								
g_{maxwin}																	14			14						22	
$g_{max, moss}$			19														45						17				
$g_{max, vasc}$																	23										
d_p	16																										
ψ_a			20			18			30	23			45		14												
h_{com}																17											
T_{RainL}																				20							
m_T															14						20						
ρ_{smin}																											
s_{dl}							21								22												
S_{dw}																											
f_{qh}													17														
m_{Rmin}																											
Δz_{cov}																											
Count	**1**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**5**	**2**	**1**	**2**	**5**	**0**	**5**	**1**	**7**	**4**	**1**	**3**	**1**	**0**	**4**	**0**	**1**	**2**	**2**

2 Supplementary Figures

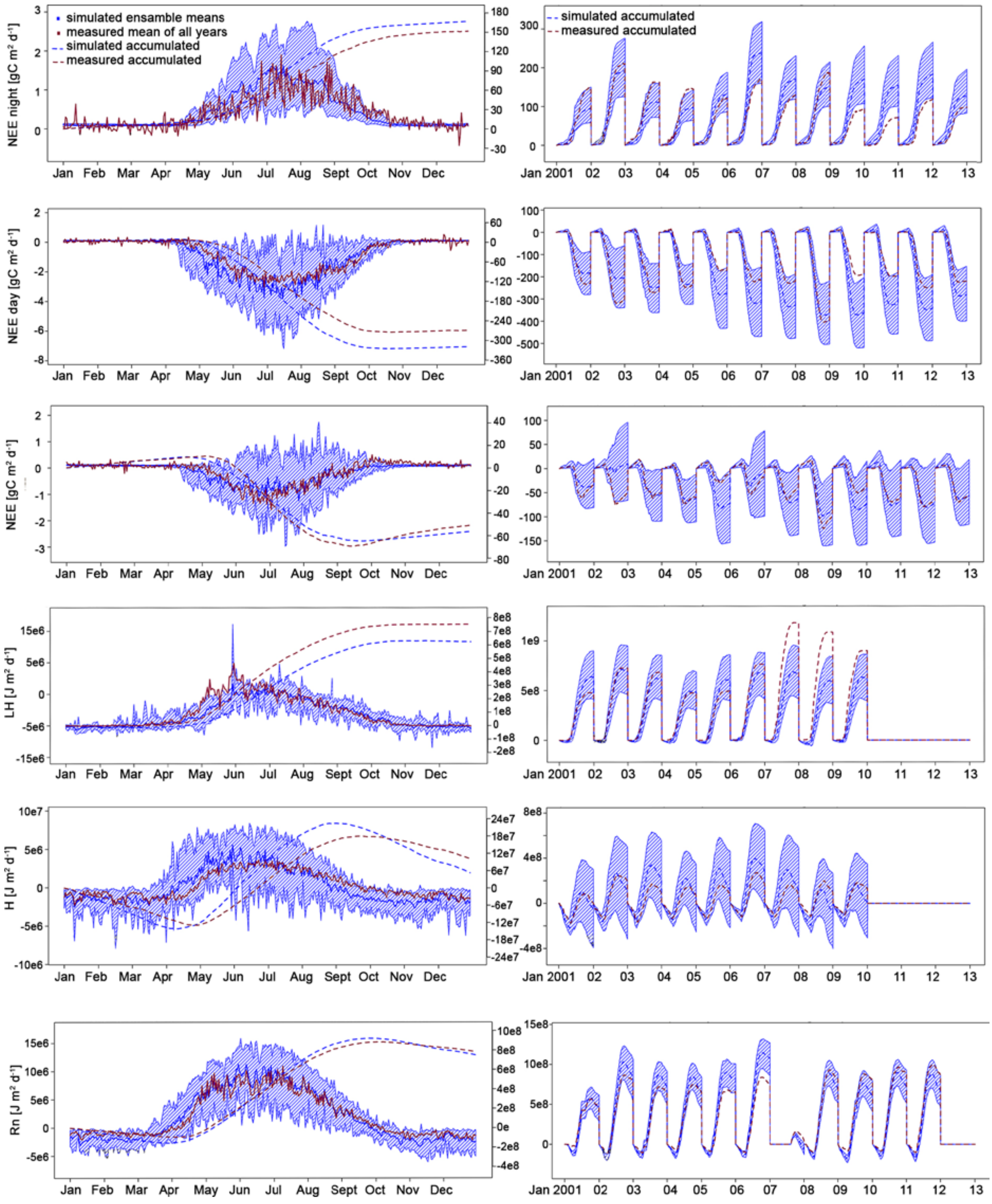

Figure S1. Model fit to observations. Left column: simulated and measured mean of all years. Right column: cumulated values for each year.

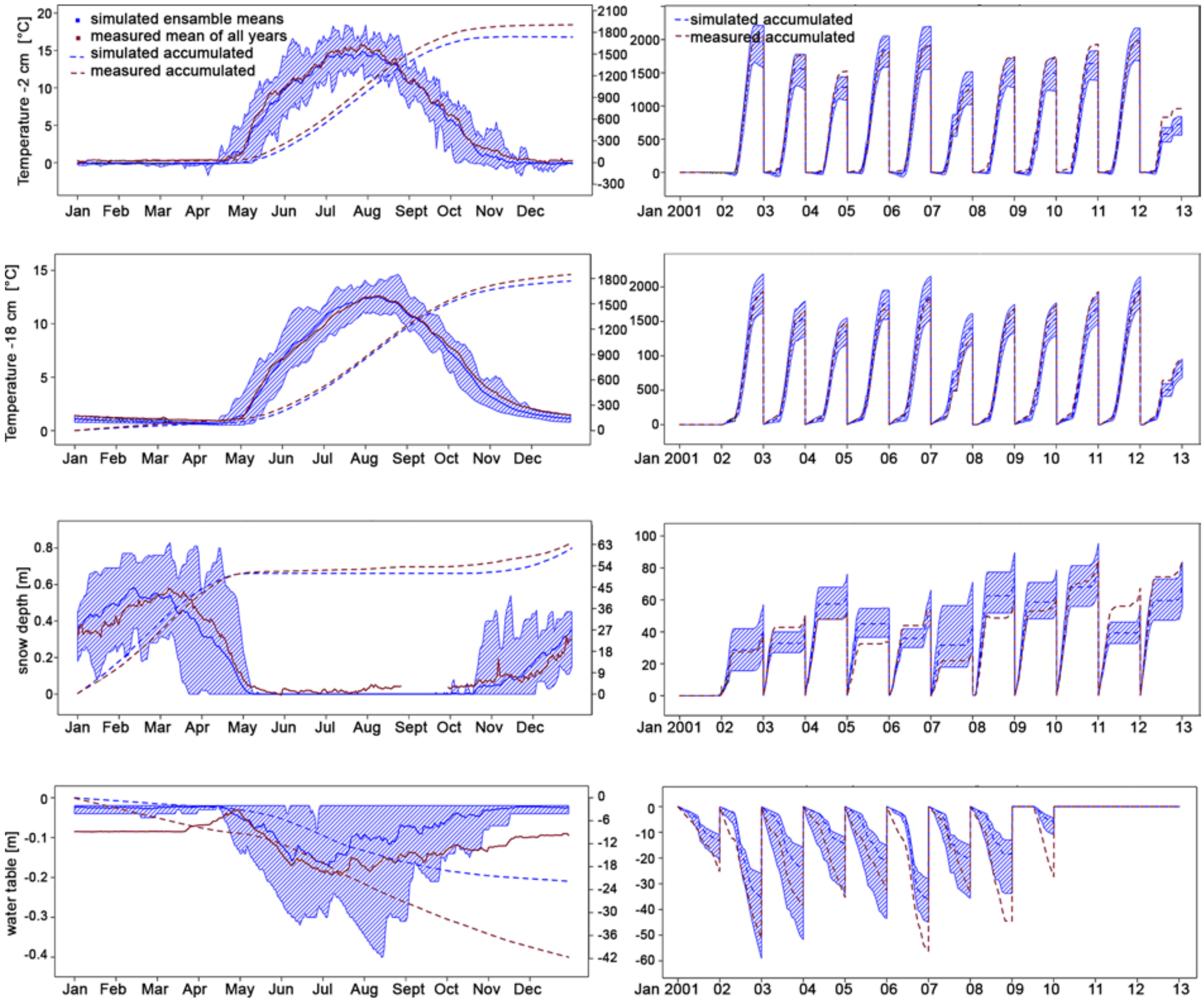

Figure S1 continued: Model fit to observations. Left column: simulated and measured mean of all years. Right column: cumulated values for each year

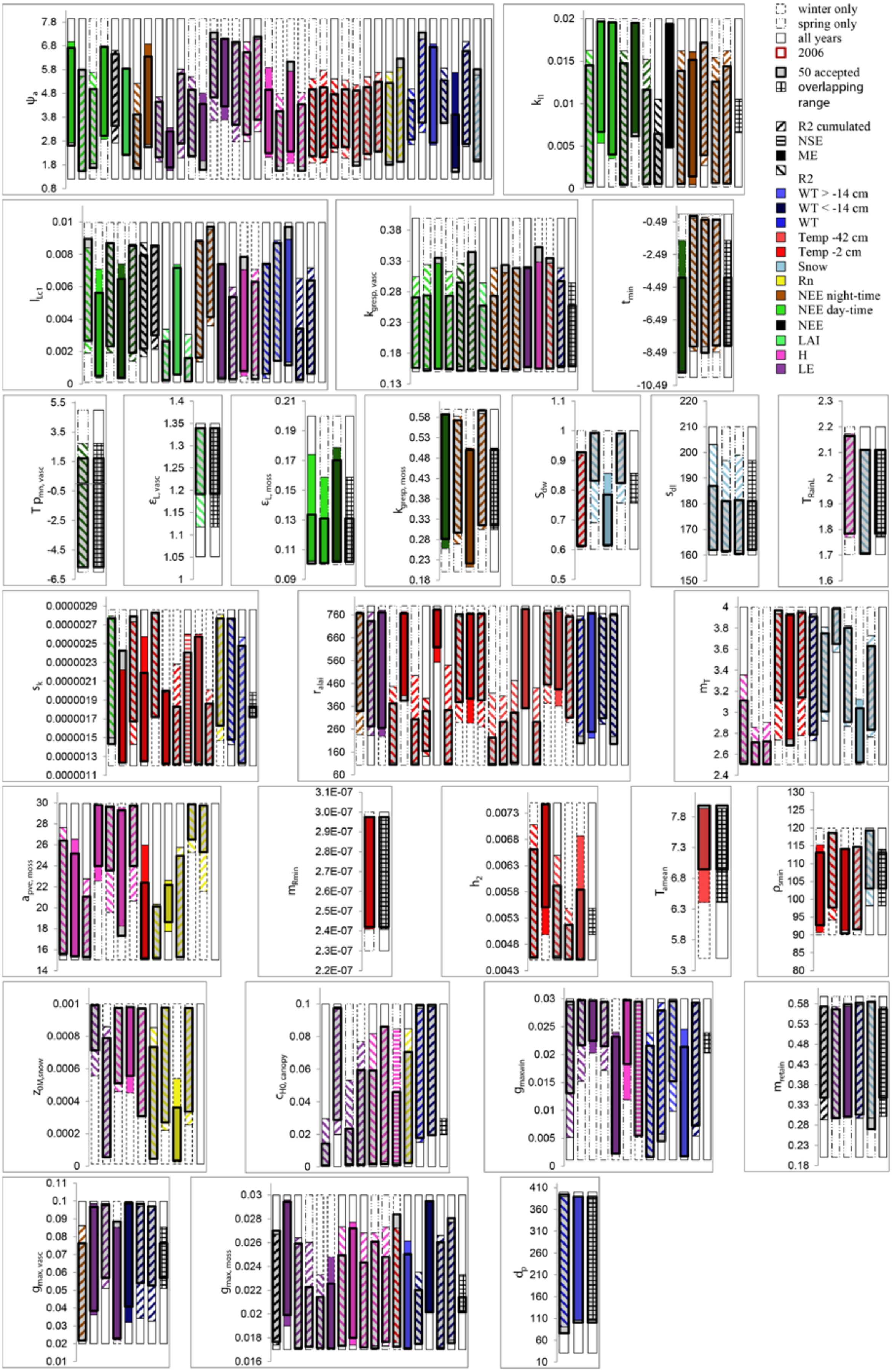

Figure S2. Accepted parameter ranges. The last bar in each bar chart shows the overlapping range. If empty, ranges are not overlapping

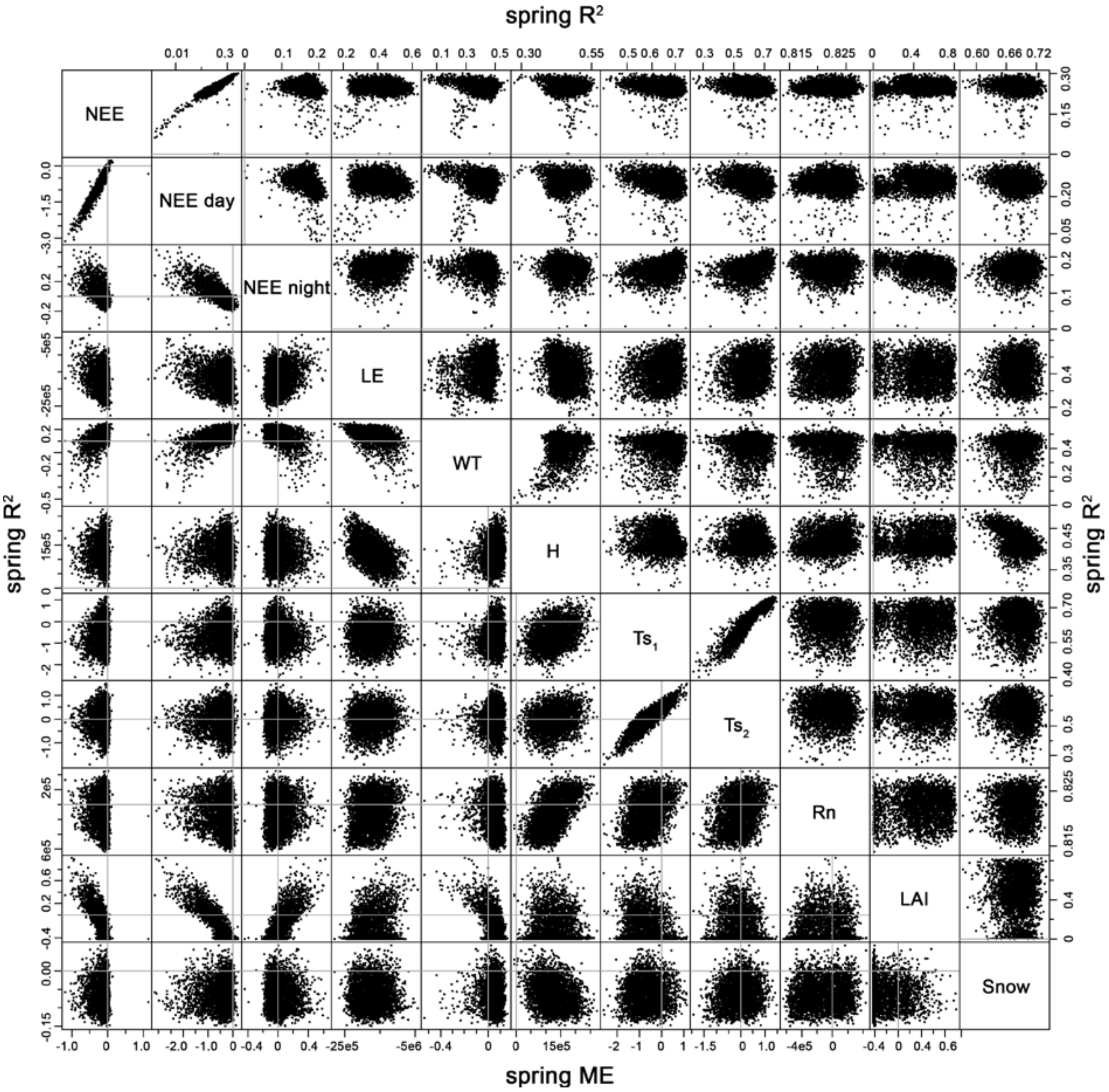

Figure S3. Correlations between performance indices in the prior distribution during spring time only. Upper panel: R2, lower panel: ME. Each of the dots represents a parameter set. Grey lines indicate the axes through zero.

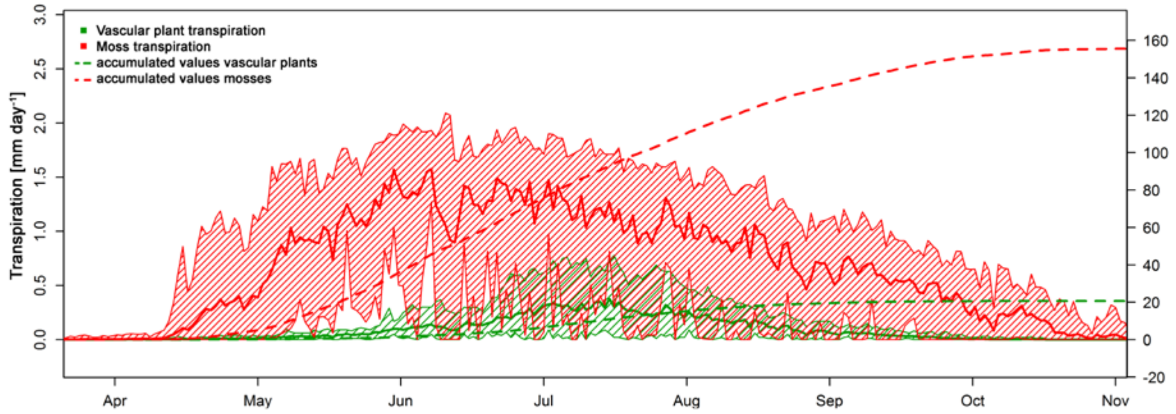

Figure S4. 12 year mean of transpiration from mosses and vascular plants. The hatched area shows the range of the 51 runs with selected performance in NEE, the solid line its mean.

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