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Supplement of

A vertically discretised canopy description for ORCHIDEE (SVN r2290) and the modifications to the energy, water and carbon fluxes

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1 Supplementary information

This document contains the supplementary figures and tables of the manuscript 'A vertically discretised canopy description for ORCHIDEE (SVN r2290) and the modifications to the energy, water and carbon fluxes'.

1.1 Figures

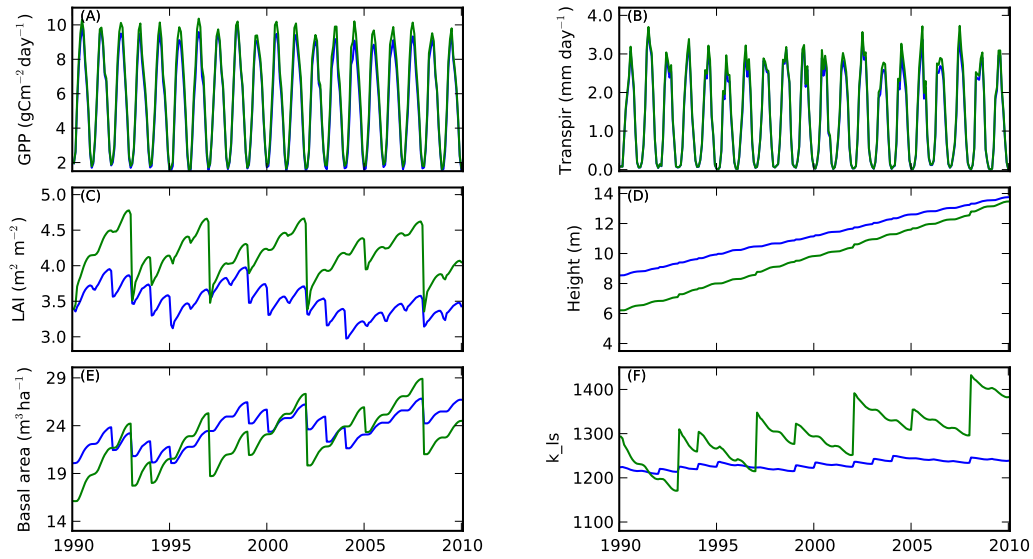


Figure S1. Impact of the optimization of k_{cmaint} and k_{lsmin} for an unmanaged Scots pine forest at 51 – 52°N, 13 – 14°E for GPP (A), transpiration (B), LAI (C), tree height (D), basal area (E) and the ratio of leaf area to sapwood area (F). The simulation with prior parameter values is shown in green ($k_{cmaint}= 0.01$ and $k_{lsmin,max} = 850 - 2000$) and the simulation with optimized values is presented in blue ($k_{cmaint}= 0.033$ and $k_{lsmin,max} = 1100 - 1395$).

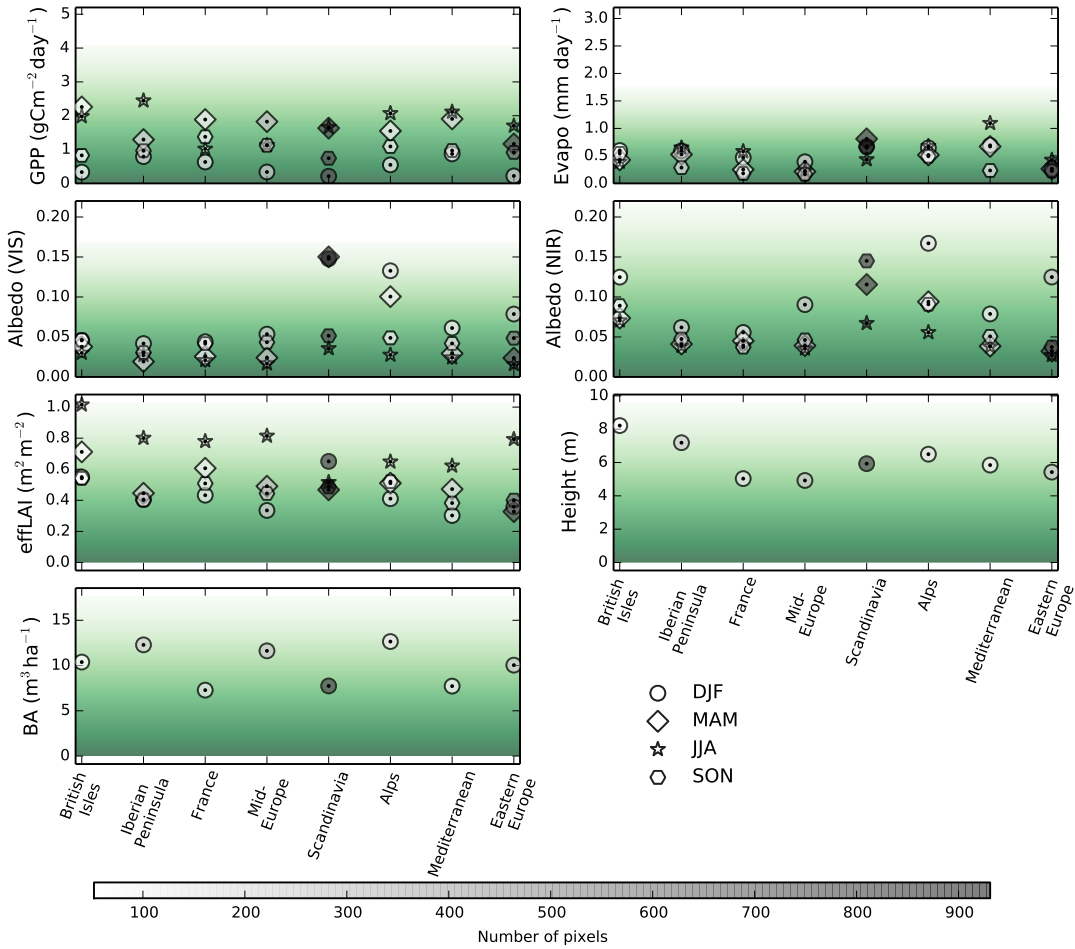


Figure S2. Root mean square error of an ORCHIDEE-CAN simulation with metaclass parameters. Results are shown for gross primary production, evapotranspiration, visible and near-infra-red albedo, effective leaf area index, basal area and height for different regions and periods (DJF: December-February, MAM: March-May, JJA: June-August, SON: September-November). The gray-scale of the symbols indicates the number of pixels included in the calculation. The transition from green to white indicates an RMSE of 100%.

1.2 Tables

Table S1. Description of the parameters in ORCHIDEE-CAN

Symbol in text	Unit	Value	Symbol in ORCHIDEE-CAN	Description	References
k_{cmaint}	-	Table S2	coeff_maint_init	Fraction of allocatable photosynthates that is consumed for maintenance and growth respiration	Ryan (1991)
k_{ls} , k_{lsmmin} , k_{lsmmax}	m	Table S2	k_latosa, k_latosa_min, k_latosa_max	Leaf area to sapwood area of an individual tree	Pothier and Margolis (1991); Bartelink (1997); Berthier et al. (2001); Mencuccini and Bonosi (2001); Wullschlegel et al. (1998); Novick et al. (2009); Schäfer et al. (2000); Samuelson et al. (2007); Gould and Harrington (2008); McDowell et al. (2002); Meadows and Hodges (2002); David et al. (2004); Limousin et al. (2012); Bréda and Granier (1996); Martin et al. (1998); Vincke et al. (2005); Margolis et al. (1995)
k_{sarr}	-	eq. 7	c0_alloc	Sapwood mass to root mass for an individual tree	Calculated from other parameters
$k_{V_{cmax}}$	$\mu\text{mol m}^{-2}\text{s}^{-1}$	Table S3	V_cmax25	Carboxylation capacity	TRY
$k_{J_{max}}/V_{cmax}$	$\mu\text{mol e}^{-}(\mu\text{mol CO}_2)^{-1}$	Table S3	arjv	Ratio of electron transport capacity to carboxylation capacity	TRY
k_{sla}	$\text{m}^2 \text{gC}^{-1}$	Table S3	sla	Specific leaf mass	TRY
k_{ρ_s}	gC m^{-3}	Table S3	pipe_density	Carbon density of sapwood	TRY; Gaspar et al. (2008); Repola (2006); Knapic et al. (2008); Jenkins et al. (2003)
k_{τ_l}	days	Table S3	tau_leaf	Leaf longevity	ICP forest, TRY
k_{τ_s}	days	Table S3	tau_sap	Sapwood longevity	Björklund (1999); Longuetaud et al. (2006); Gebauer et al. (2008); Schulze et al. (1995)

Table S1. Continuation of Table S1.

Symbol in text	Unit	Value	Symbol in ORCHIDEE-CAN	Description	References
k_{rr}	days	Table S3	tau_root	Root longevity	Brunner et al. (2013)
k_{op}	m	Table S3	pipe_tune1	Parameter in the relationship between diameter and projected crown surface area	Pretzsch and Dieler (2012)
k_{bp}	-	Table S3	pipe_tune_exp_coeff	Parameter in the relationship between diameter and projected crown surface area	Pretzsch and Dieler (2012)
k_{ncirc}	-	3	ncirc	Number of circumference classes	Assumed
$k_{\alpha}, k_{\alpha'}$	n.a.	n.a.	n.a.	Generic parameter to develop equation	n.a.
k_{β}	n.a.	n.a.	n.a.	Generic parameter to develop equation	n.a.
$k_{\alpha 1}$	m^{-1}	Table S3	pipe_tune2	Allometric constant relating tree diameter and height	Swedish, German, French and Spanish NFI
$k_{\beta 1}$	-	Table S3	pipe_tune3	Allometric constant relating tree diameter and height	Swedish, German, French and Spanish NFI
$k_{\alpha 2}$	-	Table S3	alpha_self_thinning	Allometric constant of the self-thinning relationship	Swedish, German, French and Spanish NFI
$k_{\beta 2}$	-	Table S3	beta_self_thinning	Allometric constant of the self-thinning relationship	Swedish, German, French and Spanish NFI
k_m	-	1	m	Relaxation constant of intra-specific competition relationship	Assumed
k_{ddf}	-	1	death_df	Factor by which the smallest and largest circumference classes differ	Assumed
$k_{trresid}$	years	Table S3	residence_time	Residence time of tree, accounting for mortality due to pest, diseases and windfall	Assumed

Table S1. Continuation of Table S1.

Symbol in text	Unit	Value	Symbol in ORCHIDEE-CAN	Description	References
k_{lcon}	$m s^{-1} MPa^{-1}$	Table S3	k_leaf	Hydraulic conductivity of leaves	Hickler et al. (2006); Sellin et al. (2013); Aranda et al. (2005) ;
k_{scon}	$m^2 s^{-1} MPa^{-1}$	Table S3	k_sap	Hydraulic conductivity of sapwood	Manzoni et al. (2013); Cochard (1992); Magnani et al. (2000); Quero et al. (2011); Sellin et al. (2013)
k_{rcon}	$m^3 kg^{-1} s^{-1} MPa^{-1}$	Table S3	k_root	Hydraulic conductivity of roots	Magnani et al. (2000); Steudle (2000); Armeth et al. (1996)
$k_{\psi50}$	MPa	Table S3	psi_50	Soil water potential that causes 50% loss of xlem conductivit through cavitation	Choat et al. (2012); Manzoni et al. (2013); Corcuera et al. (2004); Fichot et al. (2010, 2011); Hickler et al. (2006); Cochard (1992)
$k_{\psi lmin}$	MPa	Table S3	psi_leaf	Minimal leaf water potential	Choat et al. (2012); Martinez-Vilalta et al. (2004); Magnani et al. (2000); Limousin et al. (2012); Hacke and Sauter (1995); Sellin et al. (2013); Schulze et al. (1985)
k_c	-	3	c_cavitation	Shape parameter for vulnerability curve for cavitation	Hickler et al. (2006)
$k_{\alpha 1v}$	-	0.556	a_viscosity(1)	Empirical parameter for the temperature dependence of hydraulic resistance	Cochard et al. (2000)
$k_{\alpha 2v}$	-	0.022	a_viscosity(2)	Empirical parameter for the temperature dependence of hydraulic resistance	Cochard et al. (2000)
$k_{\lambda, LE}$	$J kg^{-1}$		chalex0	Latent heat of evaporation	
$k_{\rho a, i}$	$kg m^{-3}$		rau	Air density, calculated from air temperature and pressure	
$k_{\rho v, i}$	$kg m^{-3}$	1000	rho_veg	Leaf density, assumed to be equal to the heat capacity of water	

Table S1. Continuation of Table S1. Soil parameters are given for each soil tile: BS, bare soil, GC: grasses and crops, T:trees

Symbol in text	Unit	Value	Symbol in ORCHIDEE-CAN	Description	References
$k_{lh_{c,i}}$	J kg K ⁻¹	4.18 10 ⁻³	jtheta	Leaf layer heat capacity	
$k_{\rho w}$	g cm ⁻³		rho_h2o	Density of water at 15° C	
k_g	m s ⁻²		cte_grav	Gravitational constant	
$k_{k,i}$	m ² s ⁻¹		k_eddy	Diffusivity coefficient	
k_{av}	m ⁻¹	0.0075 (BS) 0.0036 (GC)	avan_fao	Van Genuchten (1980) coefficient α	Carsel and Parrish (1988)
		0.0019 (T)			
k_{swcs}	m ³ m ⁻³	0.41 (BS) 0.43 (GC) 0.41 (T)	mcs_fao	Saturated soil water content	Carsel and Parrish (1988)
k_{swcr}	m ³ m ⁻³	0.065 (BS) 0.078 (GC) 0.095 (T)	mcr_fao	Residual soil water content	Carsel and Parrish (1988)
k_{mv}	-	Calculated	-	Van Genuchten (1980) coefficient m	Carsel and Parrish (1988)
		from n			
k_{nv}	-	1.89 (BS) 1.56 (GC) 1.31 (T)	nvan_fao	Van Genuchten (1980) coefficient n	Carsel and Parrish (1988)
$Leaf_{ssa}^{vis}$	-	Table S4	leaf_ssa_vis	Leaf single scattering albedo, visible light	Derived from Pinty et al. (2007)
$Leaf_{ssa}^{nir}$	-	Table S4	leaf_ssa_nir	leaf single scattering albedo, near infrared	Derived from Pinty et al. (2007)
$Leaf_{psd}^{vis}$	-	Table S4	leaf_psd_vis	Leaf preferred scattering direction, visible light	Derived from Pinty et al. (2007)
$Leaf_{psd}^{nir}$	-	Table S4	leaf_psd_nir	Leaf preferred scattering direction, near infrared	Derived from Pinty et al. (2007)
Bgd_{ref}^{vis}	-	Table S4	bgd_reflectance_vis	Background reflectance, visible light	Derived from Pinty et al. (2007)
Bgd_{ref}^{nir}	-	Table S4	bgd_reflectance_nir	Background reflectance, near infrared	Derived from Pinty et al. (2007)

Table S2. Parameter values per species group for allocation and mortality. Te, Temperate; Bo, Boreal; Ne, Needleleaf; Br, Broadleaved; E, Evergreen; S, Summergreen.

MTC	Species (PFT)	k_{cmaint}	k_{lsmmin}	k_{lsmmax}	k_{oap}	k_{bp}	k_{r-l}	k_{r-s}	k_{r-r}	k_{pos}	$k_{\alpha 1}$	$k_{\beta 1}$	$k_{\alpha 2}$	$k_{\beta 2}$	k_{rresid}
TeNeE	<i>Pinus sylvestris</i>	0.0330	1100	1395	97	1.47	720	13870	224	200000	33	0.63	1236	-0.57	250
TeNeE	<i>Pinus pinaster</i>	0.0175	250	1745	54	1.05	1670	15148	275	235000	29	0.53	1626	-0.59	250
TeNeE	<i>Picea sp.</i>	0.0379	1350	3900	113	0.85	1460	16425	326	190000	35	0.54	1507	-0.59	250
TeBrE	<i>Quercus</i>	0.0291	675	3079	146	1.52	677	11680	191	480000	14	0.33	1678	-0.64	250
	<i>ilex/suber</i>														
TeBrS	<i>Betula sp.</i>	0.0097	2600	3600	91	1.16	146	11680	280	238000	35	0.66	1272	-0.61	200
TeBrS	<i>Fagus sylvatica</i>	0.0130	2700	4430	173	1.70	183	11680	280	334000	32	0.52	1000	-0.60	200
TeBrS	<i>Quercus</i>	0.0021	3300	4380	173	1.70	183	11680	280	300000	32	0.52	1100	-0.60	200
	<i>robur/petraea</i>														
TeBrS	<i>Populus sp.</i>	0.0160	5000	5100	139	1.40	183	11680	280	176000	39	0.50	1407	-0.60	200
BoNeE	<i>Pinus sylvestris</i>	0.0346	2600	4300	70	1.49	1160	11680	224	200000	41	0.59	991	-0.58	350
BoNeE	<i>Picea sp.</i>	0.0467	2500	3000	40	1.11	2160	11680	368	190000	45	0.57	1166	-0.58	350
BoBrS	<i>Betula sp.</i>	0.0767	4800	5000	77	1.21	146	11680	280	238000	41	0.66	1272	-0.60	150
BoNeS	<i>Larix sp.</i>	0.1100	5000	6000	83	1.40	180	13870	360	248750	30	0.52	1426	-0.60	350

Table S3. Parameter values per species group for hydraulic architecture and photosynthesis. Te, Temperate; Bo, Boreal; Ne, Needleleaf; Br, Broadleaved; E, Evergreen; S, Summergreen.

MTC	Species (PFT)	k_{lcon}	k_{scon}	k_{rcon}	$k_{\psi50}$	$k_{\psi/min}$	$k_{V_{cmax}}$	$k_{J_{max}/V_{cmax}}$	k_{sla}
TeNeE	<i>Pinus sylvestris</i>	$1.50 \cdot 10^{-7}$	$8.50 \cdot 10^{-4}$	$2.30 \cdot 10^{-7}$	-3.36	-1.60	87	2.48	0.0114
TeNeE	<i>Pinus pinaster</i>	$1.50 \cdot 10^{-7}$	$3.52 \cdot 10^{-4}$	$3.30 \cdot 10^{-7}$	-3.22	-2.30	90	1.72	0.005
TeNeE	<i>Picea sp.</i>	$1.50 \cdot 10^{-7}$	$4.00 \cdot 10^{-4}$	$4.29 \cdot 10^{-7}$	-3.98	-1.95	61	1.91	0.0072
TeBrE	<i>Quercus ilex/suber</i>	$1.50 \cdot 10^{-7}$	$1.08 \cdot 10^{-4}$	$2.56 \cdot 10^{-6}$	-3.83	-4.48	39	2.22	0.0137
TeBrS	<i>Betula sp.</i>	$3.50 \cdot 10^{-7}$	$3.00 \cdot 10^{-3}$	$2.51 \cdot 10^{-7}$	-2.40	-0.94	77	2.18	0.0288
TeBrS	<i>Fagus sylvatica</i>	$3.50 \cdot 10^{-7}$	$3.60 \cdot 10^{-4}$	$2.01 \cdot 10^{-7}$	-3.98	-2.15	40	2.08	0.0330
TeBrS	<i>Quercus robur/petraea</i>	$3.50 \cdot 10^{-7}$	$1.03 \cdot 10^{-3}$	$3.02 \cdot 10^{-7}$	-3.23	-2.94	65	2.04	0.0286
TeBrS	<i>Populus sp.</i>	$3.50 \cdot 10^{-7}$	$1.46 \cdot 10^{-3}$	$2.51 \cdot 10^{-7}$	-2.00	-1.62	137	1.40	0.0256
BoNeE	<i>Pinus sylvestris</i>	$1.50 \cdot 10^{-7}$	$8.50 \cdot 10^{-4}$	$2.30 \cdot 10^{-7}$	-2.40	-1.60	50	2.48	0.008
BoNeE	<i>Picea sp.</i>	$1.50 \cdot 10^{-7}$	$4.00 \cdot 10^{-4}$	$2.45 \cdot 10^{-7}$	-3.20	-1.95	87	2.09	0.0066
BoBrS	<i>Betula sp.</i>	$3.52 \cdot 10^{-7}$	$3.00 \cdot 10^{-3}$	$2.51 \cdot 10^{-7}$	-3.15	-0.94	77	2.18	0.0288
BoNeS	<i>Larix sp.</i>	$2.50 \cdot 10^{-7}$	$5.82 \cdot 10^{-4}$	$3.00 \cdot 10^{-7}$	-3.66	-1.60	40	2.00	0.0218

Table S4. Parameter values per species group for radiation transfer and photosynthesis. Te, Temperate; Bo, Boreal; Ne, Needleleaf; Br, Broadleaved; E, Evergreen; S, Summergreen.

MTC	Species (PFT)	Leaf_ssa_vis	Leaf_ssa_nir	Leaf_psd_vis	Leaf_psd_nir	Bgrd_ref_vis	Bgrd_ref_nir
TeNeE	<i>Pinus sylvestris</i>	0.1529	0.74131	1.0400	2.1160	0.056095	0.098511
TeNeE	<i>Pinus pinaster</i>	0.1703	0.78242	1.0946	2.2343	0.058601	0.098511
TeNeE	<i>Picea sp.</i>	0.1504	0.74644	1.0395	2.1346	0.042981	0.073559
TeBrE	<i>Quercus ilex/suber</i>	0.1343	0.73407	1.0255	2.0953	0.055900	0.095732
TeBrS	<i>Betula sp.</i>	0.1722	0.72176	1.0359	2.0575	0.088728	0.14427
TeBrS	<i>Fagus sylvatica</i>	0.1415	0.76699	1.0711	2.1959	0.051854	0.089514
TeBrS	<i>Quercus robur/petraea</i>	0.1562	0.74554	1.0433	2.1163	0.100240	0.17743
TeBrS	<i>Populus sp.</i>	0.1395	0.72523	1.0214	2.0733	0.057965	0.093873
BoNeE	<i>Pinus sylvestris</i>	0.1529	0.74131	1.0400	2.1160	0.056095	0.093891
BoNeE	<i>Picea sp.</i>	0.1504	0.74644	1.0359	2.1346	0.042981	0.073559
BoBrS	<i>Betula sp.</i>	0.1722	0.72176	1.1753	2.0575	0.088728	0.14427
BoNeS	<i>Larix sp.</i>	0.1512	0.84980	1.1753	2.4347	0.051740	0.08372

Table S5. Description of the forest management strategies in ORCHIDEE-CAN. For the ease of presentation the Relative Density Index was calculated for a stand with 750 trees ha^{-1} based on the species specific parameters for $\alpha_{\text{rdi_upper}}$, $\beta_{\text{rdi_upper}}$, $\alpha_{\text{rdi_lower}}$, $\beta_{\text{rdi_lower}}$. First thinning height is the height that needs to be reached by at least 100 trees before thinning occurs.

Parameter	Units	ORCHIDEE-CAN	Unmanaged	High stand	Coppice	SRC
Initial density	tree ha^{-1}	nmaxtrees	6,000 – 15,000	6,000 – 15,000	6,000 – 15,000	6,000 – 15,000
Initial height	m	height_init_min	2 – 3	2 – 3	2 – 3	2 – 3
	m	height_init_max	3 – 4	3 – 4	3 – 4	3 – 4
Self-thinning	tree m^{-2}	alpha_self_thinning	991 – 1678	991 – 1678	991 – 1678	991 – 1678
	-	beta_self_thinning	-0.57 – -0.64	-0.57 – -0.64	-0.57 – -0.64	-0.57 – -0.64
Longevity	year	residence_time	200 – 350	200 – 350	200 – 350	200 – 350
First thinning height	m	h_first	n.a.	6 – 8	n.a.	n.a.
Relative density index	-	n.a.	n.a.	0.6 – 0.9	n.a.	n.a.
Stand replacing density	tree ha^{-1}	ntrees_dia_profit	100	100	n.a.	n.a.
Harvest diameter	m	largest_tree_dia	n.a.	0.2 – 0.6	n.a.	n.a.
Coppice diameter	m	coppice_diameter	n.a.	n.a.	0.2	n.a.
Rotation length	year	src_rot_length	n.a.	n.a.	n.a.	3
Number of rotations	-	src_nrots	n.a.	n.a.	n.a.	10
Fuelwood diameter	m	fuelwood_diameter	n.a.	0.2 – 0.3	0.2 – 0.3	0.2 – 0.3

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