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Point-scale multi-objective calibration of the Community Land Model (version 5.0) using in situ observations of water and energy fluxes and variables

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Table S1: Look-up table, initial and optimized LAI for all scenarios.

Scenario		X	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
Target variable		Control run (look-up table parameter value)	Initial model run (initial parameter value)	LE	LE and q	LE and SWC	LE, q and SWC	H	H and q	H and SWC	H, q and SWC	H and Tsoil	H, q, SWC and Tsoil	q	LE and H	LE, H, q and SWC
Leaf Area Index																
Jan	-	0.53	0.5	0.7	0.9	0.5	1.1	0.5	0.5	0.5	0.6	0.4	0.5	0.6	0.5	0.6
Feb	-	0.3	0.5	0.5	0.4	0.7	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Mar	-	0.21	1	1.3	1.6	1.2	1.6	1.1	1.0	1.0	1.1	1.2	1.0	0.9	1.2	1.1
Apr	-	0.5	2.8	1.6	1.7	2.8	2.1	2.7	2.7	2.8	2.4	4.4	5.3	2.2	2.6	2.3
May	-	1.51	3.5	2.6	2.4	2.8	2.1	3.3	2.8	3.5	3.1	7.1	6.7	3.3	2.9	3.4
Jun	-	2.65	4.5	5.0	4.7	4.6	4.9	4.1	4.2	4.8	5.4	5.0	5.6	4.7	4.3	4.6
Jul	-	1.97	4	1.1	1.2	2.7	1.7	3.2	1.7	3.7	3.2	7.8	9.5	4.2	2.4	2.5
Aug	-	1.27	0.5	0.8	0.6	0.7	1.1	0.5	0.4	0.5	0.6	0.8	0.7	0.5	0.6	0.6
Sep	-	0.98	1	2.2	2.2	1.3	2.2	1.1	1.4	1.1	1.1	2.2	3.4	1.0	1.3	1.6
Oct	-	0.85	1	1.5	0.8	1.2	2.0	1.0	1.1	1.1	1.0	1.3	1.3	0.9	1.0	1.2
Nov	-	0.93	1	1.0	1.7	1.0	0.7	1.2	1.5	1.0	1.1	1.2	1.6	1.0	1.0	1.3
Dec	-	0.65	1	1.3	1.1	1.0	1.2	1.0	1.4	1.0	0.9	1.1	1.1	1.0	1.0	0.9

Table S2: Look-up table, initial and optimized optical parameters for all scenarios.

Scenario			X	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
Target variable			Control run (look-up table parameter value)	Initial model run (initial parameter value)	LE	LE and q	LE and SWC	LE, q and SWC	H	H and q	H and SWC	H, q and SWC	H and Tsoil	H, q, SWC and Tsoil	q	LE and H	LE, H, q and SWC
leaf reflectance - shortwave	rholvis	-	0.11	0.11	0.03	0.03	0.09	0.03	0.1	0.08	0.11	0.09	0.08	0.09	0.09	0.08	0.09
leaf reflectance – longwave	rholnir	-	0.35	0.35	0.32	0.34	0.32	0.39	0.37	0.45	0.37	0.37	0.42	0.34	0.39	0.37	0.39
stem reflectance - shortwave	rhosvis	-	0.31	0.31	0.22	0.17	0.22	0.31	0.23	0.22	0.29	0.26	0.26	0.23	0.27	0.32	0.3
stem reflectance – longwave	rhosnir	-	0.53	0.53	0.51	0.38	0.41	0.36	0.37	0.3	0.45	0.38	0.31	0.30	0.4	0.42	0.39
leaf transmittance - shortwave	taulvis	-	0.05	0.05	0.04	0.02	0.05	0.02	0.05	0.04	0.05	0.05	0.04	0.05	0.05	0.05	0.05
leaf transmittance – longwave	taulnir	-	0.34	0.34	0.47	0.45	0.45	0.39	0.38	0.31	0.38	0.4	0.34	0.41	0.38	0.4	0.38
stem transmittance - shortwave	tausvis	-	0.12	0.12	0.1	0.1	0.11	0.09	0.12	0.1	0.12	0.12	0.12	0.11	0.11	0.12	0.13
stem transmittance – longwave	tausnir	-	0.25	0.25	0.2	0.35	0.21	0.31	0.24	0.26	0.25	0.2	0.17	0.17	0.22	0.18	0.26

Table S3: .pst file for PEST, Scenario D

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pcf

* control data

restart regularisation

47 315864 1 30 36

2 7 double point 1 0 0

10 -3.0 0.3 0.05 8

3 3 0.01

0.1

0 0.005 4 3 0.01 3

1 1 1

* singular value decomposition

2

30 5E 7

0

* parameter groups

Params relative 0.01 0.0001 switch 2.0 parabolic

* parameter data

sand1_____ log factor 87.71872 0.1 150 params 1.00.0 1

sand2_____ log factor 56.89878 0.1 150 params 1.0 0.0 1

clay1_____ log factor 13.65003 0.1 100 params 1.0 0.0 1

clay2_____ log factor 14.30049 0.1 100 params 1.0 0.0 1

lai_jan_____ log factor 1.103101 0.001 50 params 1.0 0.0 1

lai_feb_____ log factor 0.3145748 0.001 50 params 1.0 0.0 1

lai_mar_____ log factor 1.580888 0.001 50 params 1.0 0.0 1

lai_apr_____ log factor 2.065890 0.001 50 params 1.0 0.0 1

lai_may_____ log factor 2.114882 0.001 50 params 1.0 0.0 1

lai_jun_____ log factor 4.899428 0.001 50 params 1.0 0.0 1

lai_jul_____ log factor 1.647559 0.001 50 params 1.0 0.0 1

lai_aug_____ log factor 1.065331 0.001 50 params 1.0 0.0 1

lai_sep_____ log factor 2.240715 0.001 50 params 1.0 0.0 1

lai_oct_____	log	factor	2.025805	0.001	50	params	1.0 0.0 1
lai_nov_____	log	factor	0.6485091	0.001	50	params	1.0 0.0 1
lai_dec_____	log	factor	1.156557	0.001	50	params	1.0 0.0 1
height_top__	log	factor	1.036569	0.01	50	params	1.0 0.0 1
displar_c___	log	factor	0.6168842	0.01	5	params	1.0 0.0 1
dleaf_c_____	log	factor	3.3461677E-02	0.001	0.5	params	1.0 0.0 1
z0mr_c______	log	factor	7.8161609E-02	0.01	1	params	1.0 0.0 1
medlyn_c____	log	factor	4.711604	0.1	50	params	1.0 0.0 1
rootprof_c__	log	factor	0.5641189	0.001	1	params	1.0 0.0 1
rholvis_c___	log	factor	3.0766245E-02	0.01	1	params	1.0 0.0 1
rholnir_c___	log	factor	0.3934365	0.01	1	params	1.0 0.0 1
rhosvis_c___	log	factor	0.3063361	0.01	1	params	1.0 0.0 1
rhosnir_c___	log	factor	0.3618872	0.01	1	params	1.0 0.0 1
taulvis_c___	log	factor	2.3902092E-02	0.01	1	params	1.0 0.0 1
taulnir_c___	log	factor	0.3858137	0.01	1	params	1.0 0.0 1
tausvis_c___	log	factor	9.3574092E-02	0.01	1	params	1.0 0.0 1
tausnir_c___	log	factor	0.3056314	0.01	1	params	1.0 0.0 1
sai_jan_____	fixed	factor	0.1239475	0.001	50	params	1.0 0.0 1
sai_feb_____	fixed	factor	0.2340765	0.001	50	params	1.0 0.0 1
sai_mar_____	fixed	factor	9.6431583E-02	0.001	50	params	1.0 0.0 1
sai_apr_____	fixed	factor	2.0598052E-02	0.001	50	params	1.0 0.0 1
sai_may_____	fixed	factor	2.0598052E-02	0.001	50	params	1.0 0.0 1
sai_jun_____	fixed	factor	2.0598052E-02	0.001	50	params	1.0 0.0 1
sai_jul_____	fixed	factor	0.6683016	0.001	50	params	1.0 0.0 1
sai_aug_____	fixed	factor	0.6886196	0.001	50	params	1.0 0.0 1
sai_sep_____	fixed	factor	0.2762972	0.001	50	params	1.0 0.0 1
sai_oct_____	fixed	factor	0.1512883	0.001	50	params	1.0 0.0 1
sai_nov_____	fixed	factor	0.1001850	0.001	50	params	1.0 0.0 1
sai_dec_____	fixed	factor	0.2685816	0.001	50	params	1.0 0.0 1
xl_c________	fixed	factor	0.5000000	0.2	0.6	params	-1.0 0.0 1
fmax	fixed	factor	0.000000	0	1	params	1.0 0.0 1
organic1____	fixed	factor	6.000000	0.1	300	params	1.0 0.0 1

organic2	fixed	factor	0.000000	0	300	params	1.0 0.0 1
soil_color	fixed	factor	13.00000	0.1	20	params	1.0 0.0 1

* observation groups

obsgrp_LE

obsgrp_R

obsgrp_SWC

obsgrp_H

obsgrp_Sout

obsgrp_Rn

regul_sand1

regul_sand2

regul_clay1

regul_clay2

regul_laijan

regul_laifeb

regul_laimar

regul_laiapr

regul_laimay

regul_laijun

regul_laijul

regul_laiaug

regul_laisep

regul_laioct

regul_lainov

regul_laidec

regul_height

regul_disp

regul_dleaf

regul_z0mr

regul_medlyn

regul_root

regul_rholv

regul_rholn

regul_rhosv

regul_rhosn

regul_taulv

regul_tauln

regul_tausv

regul_tausn

* observation data

obs_2010010100_le	-3.840600	1.153423E-03	obsgrp_le
obs_2010010101_le	-2.117845	1.153224E-03	obsgrp_le
obs_2010010102_le	-1.900800	1.153199E-03	obsgrp_le
...			
obs_2010010100_r	2.9531787E-02	0.440018	obsgrp_r
obs_2010010101_r	3.2216495E-02	0.440137	obsgrp_r
obs_2010010102_r	3.2216495E-02	0.440137	obsgrp_r
...			
obs_2010010100_swc	0.000000	0.00000	obsgrp_swc
obs_2010010101_swc	0.000000	0.00000	obsgrp_swc
obs_2010010102_swc	0.000000	0.00000	obsgrp_swc
obs_2010010103_swc	0.000000	0.00000	obsgrp_swc
...			
obs_2010010100_h	-5.893350	0.00000	obsgrp_h
obs_2010010101_h	-7.371400	0.00000	obsgrp_h
obs_2010010102_h	-8.844200	0.00000	obsgrp_h
...			
obs_2010010100_sout	1.620300	2.557215E-03	obsgrp_sout
obs_2010010101_sout	1.364500	2.557150E-03	obsgrp_sout
obs_2010010102_sout	1.417800	2.557163E-03	obsgrp_sout
...			
obs_2010010100_rn	-60.24000	1.831959E-03	obsgrp_rn

obs_2010010101_rn -57.82300 1.831513E-03 obsgrp_rn

obs_2010010102_rn -34.69850 1.827263E-03 obsgrp_rn

...

* model command line

./model.sh

* model input/output

surfdata.tpl surfdata.cdl

params.tpl params.cdl

Voulund_I2000Clm50SpRsGs.clm2.h1.2006_LE_H_Sout.ins
Voulund_I2000Clm50SpRsGs.clm2.h1.2006.cdl

Voulund_I2000Clm50SpRsGs.clm2.h2.2006_LE_H_Sout.ins
Voulund_I2000Clm50SpRsGs.clm2.h2.2006.cdl

qout_soillayer_layer11.ins qout_soillayer_layer11.csv

qout_soillayer_layer11_monthly.ins qout_soillayer_layer11_monthly.csv

h2osoi_layer1_4.ins h2osoi_layer1_4.csv

Rn_model.ins Rn_model.csv

Rn_model_monthly.ins Rn_model_monthly.csv

* prior information

sand1_____ 1.0 * log(sand1_____) = 1.954242509 1.0 regul_sand1

sand2_____ 1.0 * log(sand2_____) = 1.954242509 1.0 regul_sand2

clay1_____ 1.0 * log(clay1_____) = 0.602059991 1.0 regul_clay1

clay2_____ 1.0 * log(clay2_____) = 0.602059991 1.0 regul_clay2

lai_jan_____ 1.0 * log(lai_jan_____) = -0.301029996 1.0 regul_laijan

lai_feb_____ 1.0 * log(lai_feb_____) = -0.301029996 1.0 regul_laifeb

lai_mar_____ 1.0 * log(lai_mar_____) = 0 1.0 regul_laimar

lai_apr_____ 1.0 * log(lai_apr_____) = 0.447158031 1.0 regul_laiapr

lai_may_____ 1.0 * log(lai_may_____) = 0.544068044 1.0 regul_laimay

lai_jun_____ 1.0 * log(lai_jun_____) = 0.653212514 1.0 regul_laijun

lai_jul_____ 1.0 * log(lai_jul_____) = 0.602059991 1.0 regul_laijul

lai_aug_____ 1.0 * log(lai_aug_____) = -0.301029996 1.0 regul_laiaug

lai_sep_____ 1.0 * log(lai_sep_____) = 0 1.0 regul_laisep

lai_oct_____ 1.0 * log(lai_oct_____) = 0 1.0 regul_laioct

lai_nov_____ 1.0 * log(lai_nov_____) = 0 1.0 regul_lainov

lai_dec_____	1.0 * log(lai_dec_____) = 0	1.0	regul_laidec
height_top__	1.0 * log(height_top__) = -0.301029996	1.0	regul_height
displar_c___	1.0 * log(displar_c___) = -0.167491087	1.0	regul_disp
dleaf_c_____	1.0 * log(dleaf_c_____) = -1.397940009	1.0	regul_dleaf
z0mr_c______	1.0 * log(z0mr_c______) = -0.920818754	1.0	regul_z0mr
medlyn_c____	1.0 * log(medlyn_c____) = 0.762678561	1.0	regul_medlyn
rootprof_c__	1.0 * log(rootprof_c__) = -0.025488307	1.0	regul_root
rholvis_c___	1.0 * log(rholvis_c___) = -0.958607315	1.0	regul_rholv
rholnir_c___	1.0 * log(rholnir_c___) = -0.455931956	1.0	regul_rholn
rhosvis_c___	1.0 * log(rhosvis_c___) = -0.508638306	1.0	regul_rhosv
rhosnir_c___	1.0 * log(rhosnir_c___) = -0.27572413	1.0	regul_rhosn
taulvis_c___	1.0 * log(taulvis_c___) = -1.301029996	1.0	regul_taulv
taulnir_c___	1.0 * log(taulnir_c___) = -0.468521083	1.0	regul_tauln
tausvis_c___	1.0 * log(tausvis_c___) = -0.920818754	1.0	regul_tausv
tausnir_c___	1.0 * log(tausnir_c___) = -0.602059991	1.0	regul_tausn

* regularisation

0 0

1.0 1.0e-10 1.0e10

1.3 1.0e-2