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Temporal interpolation of land surface fluxes derived from remote sensing – results with an unmanned aerial system

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List of abbreviations for model variables and parameters

Latin alphabet

A	Surface albedo (-)
b	the slope of the retention curve for the force-restore thermal coefficient (-)
C_d	Diurnal periodicity (h^{-1})
C_p	Specific heat capacity of air ($J \cdot kg^{-1} \cdot K^{-1}$)
C_{sat}	Force-restore thermal coefficient for saturated soil ($K \cdot m^2 \cdot J^{-1}$)
C_T	Force-restore thermal coefficient for the surface heat transfer ($K \cdot m^2 \cdot J^{-1}$)
C_{veg}	Force-restore thermal coefficient for vegetation ($K \cdot m^2 \cdot J^{-1}$)
CWS	Canopy Water Storage (m)
CWS_{in}	Initial canopy water storage (m)
d	Zero displacement height (m)
D_0	Empirical coefficient for VPD constraint (Pa)
f_g	Green canopy fraction (-)
f_M	Plant moisture constraint (-)
f_{Ta}	Plant temperature constraint (-)
f_{SM}	SM constraint (-)
f_{VPD}	Vapor pressure deficit constraint (-)
f_{APAR}	Fraction of PAR absorbed by green vegetation cover (-)
f_{IPAR}	Fraction of PAR intercepted by total vegetation cover (-)
G	Ground heat flux ($W \cdot m^{-2}$)
g	Gravitational acceleration ($m \cdot s^{-2}$)
GPP	Gross Primary Productivity ($\mu mol \cdot C \cdot m^{-2} \cdot s^{-1}$)
H	Sensible heat flux ($W \cdot m^{-2}$)
h_c	Canopy height (m)
k	von Karman constant (0.4)
kB-1	Parameter to account for difference of aerodynamic and radiometric temperatures (-)
K_s	Saturated hydraulic conductivity ($m \cdot s^{-1}$)
LAI	Leaf area index ($m^2 \cdot m^{-2}$)
LE	Latent heat flux ($W \cdot m^{-2}$)
LW_{in}	Incoming longwave radiation ($W \cdot m^{-2}$)
LW_{out}	Outgoing longwave radiation ($W \cdot m^{-2}$)
n	Fitting parameter in the Mualem model depending on the pore size (-)
NDVI	Normalized Difference Vegetation Index (-)
P	Precipitation ($mm \cdot h^{-1}$)
PAR	Photosynthetically active radiation ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
PAR_c	PAR intercepted by the canopy ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
PAR_s	PAR for the soil ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
P_e	Effective precipitation rate ($mm \cdot h^{-1}$)
P_s	Air pressure (Pa)
Q_d	Soil water drainage ($m \cdot s^{-1}$)
Q_s	Surface runoff ($m \cdot s^{-1}$)
Q_{inf}	Infiltration ($m \cdot s^{-1}$)
r_a	Aerodynamic resistance for heat transfer ($s \cdot m^{-1}$)
r_{aN}	Aerodynamic resistance for heat transfer under neutral conditions ($s \cdot m^{-1}$)
RH	Relative humidity (%)
R_{iB}	Bulk Richardson number (-)

Rn Net radiation ($W \cdot m^{-2}$)
Rnc Net radiation for the canopy ($W \cdot m^{-2}$)
Rns Net radiation for the soil ($W \cdot m^{-2}$)
SAVI Soil adjusted vegetation index (-)
SR Simple ratio vegetation index (-)
SW_{in} Incoming shortwave radiation ($W \cdot m^{-2}$)
SW_{out} Outgoing shortwave radiation ($W \cdot m^{-2}$)
SWS Actual soil water storage (m)
SWS_{in} Initial soil water storage (m)
SWS_{max} Maximum soil water storage (m)
T_a Air temperature (°C)
T_d Deep soil temperature (°C)
T_{d0} Initial deep soil temperature (°C)
T_o Optimum plant growth temperature (°C)
T_s Surface temperature (°C)
T_{s0} Initial surface temperature (°C)
u Wind speed ($m \cdot s^{-1}$)
VPD Vapor pressure deficit (Pa)
z Velocity reference height (m)
z_{oh} Aerodynamic roughness length for the heat transfer (m)
z_{om} Aerodynamic roughness length for momentum (m)

Greek alphabet

α PT coefficient (-)
γ Psychrometric constant (0.066 $kPa \cdot °C^{-1}$)
Δ Slope of saturation-to-vapor pressure curve ($kPa \cdot °C^{-1}$)
ε Surface emissivity (-)
ε_{max} Maximum light use efficiency ($\mu mol \cdot C \cdot m^{-2} \cdot MJ^{-1}$)
θ Volumetric soil moisture ($m^3 \cdot m^{-3}$)
θ_s Saturated soil moisture ($m^3 \cdot m^{-3}$)
θ_r Residual soil moisture ($m^3 \cdot m^{-3}$)
λEi Evaporation of intercepted water ($W \cdot m^{-2}$)
λEc Transpiration ($W \cdot m^{-2}$)
λEs Soil evaporation ($W \cdot m^{-2}$)
ρ Air density ($kg \cdot m^{-3}$)
σ Stefan-Boltzmann constant (5.670367×10^{-8} $kg \cdot s^{-3} \cdot K^{-4}$)
Ψ_h Stability correction factor for sensible heat flux (-)
Ψ_m Stability correction factor for momentum (-)

Table S1. Environmental constraints for the joint ET and GPP model (Wang et al., 2018). The extinction coefficients for PAR (k_{PAR}) and for net radiation (k_{Rn}) were equal to 0.5 and 0.6, respectively (Fisher et al., 2008; Impens and Lemeur, 1969; Ross, 1975). RH is the relative humidity.

Parameter	Description	Equation	Reference
f_g	Green canopy fraction	$f_g = f_{APAR}/f_{IPAR}$	Fisher et al. (2008)
f_M	Plant moisture constraint	$f_M = f_{APAR}/\max(f_{APAR})$	Fisher et al. (2008)
f_{Ta}	Plant temperature constraint	$f_{Ta} = 1.1814 \cdot [1 + e^{0.3(-T_o-10+T_a)}]^{-1}[1 + e^{0.2(T_o-10-Ta)}]^{-1}$	Potter et al. (1993)
f_{SM}	SM constraint	$f_{SM} = \theta_e$	Fisher et al. (2008)
f_{VPD}	Vapor pressure deficit constraint	$f_{VPD} = 1/(1 + VPD/D0)$	Lohammar et al. (1980)
f_{APAR}	Fraction of PAR absorbed by green vegetation cover	$f_{APAR} = 1.4\ SAVI - 0.05$	Fisher et al. (2008)
f_{IPAR}	Fraction of PAR intercepted by total vegetation cover	$f_{IPAR} = 1.0\ NDVI - 0.05$	Fisher et al. (2008)

Table S2. Information of model inputs to run SVEN at half hour time steps

Input	Description	Unit
SW_{in}	Incoming shortwave radiation	$W \cdot m^{-2}$
LW_{in}	Incoming longwave radiation	$W \cdot m^{-2}$
T_a	Air temperature	℃
RH	Relative air humidity	%
u	Wind speed	$m \cdot s^{-1}$
Ps	Air pressure	Pa
P	Precipitation	$mm \cdot h^{-1}$
h_c	Canopy height	m
NDVI	Normalized Difference Vegetation Index	\

Table S3. Information on model initial conditions

Initial conditions	Description	Unit	Initial value
CWS_{in}	Initial canopy water storage	m	0.00
SWS_{in}	Initial soil water storage	m	0.50
T_{s0}	Initial surface temperature	℃	T_a
T_{d0}	Initial deep soil temperature	℃	T_a

Table S4. Information on model outputs

Output	Description	Unit
T_s	Surface temperature	℃
T_d	Deep soil temperature	℃
LW_{out}	Outgoing longwave radiation	$W{\cdot}m^{-2}$
SW_{out}	Outgoing shortwave radiation	$W{\cdot}m^{-2}$
Rn	Net radiation	$W{\cdot}m^{-2}$
G	Ground heat flux	$W{\cdot}m^{-2}$
LE	Latent heat flux	$W{\cdot}m^{-2}$
λEi	Evaporation of intercepted water	$W{\cdot}m^{-2}$
λEc	Transpiration	$W{\cdot}m^{-2}$
λEs	Soil evaporation	$W{\cdot}m^{-2}$
H	Sensible heat flux	$W{\cdot}m^{-2}$
GPP	Gross Primary Productivity	$g{\cdot}C{\cdot}m^{-2}{\cdot}d^{-1}$
CWS	Canopy Water Storage	m
θ	Volumetric SM	$m^3{\cdot}m^{-3}$
Q_s	Surface runoff	$m{\cdot}s^{-1}$
Q_{per}	Percolation	$m{\cdot}s^{-1}$

Table S5. Parameter values of the Mualem model for different soil texture classes (Carsel and Parrish, 1988). θ_r is the residual soil moisture ($m^3 \cdot m^{-3}$). θ_s is the saturated soil moisture ($m^3 \cdot m^{-3}$). n is the fitting parameter of the Mualem model. K_s is the infiltration rate for the saturated soil ($mm \cdot h^{-1}$). Values in the brackets are standard deviations.

Texture class	θ_r	θ_s	n	K_s
Sand	0.045 (0.010)	0.43 (0.06)	2.68 (0.29)	297.00 (156.0)
Loamy sand	0.057 (0.015)	0.41 (0.09)	2.28 (0.27)	145.90 (113.6)
Sandy loam	0.065 (0.017)	0.41 (0.09)	1.89 (0.17)	44.20 (56.3)
Loam	0.078 (0.013)	0.43 (0.10)	1.56 (0.11)	10.40 (18.2)
Silt	0.034 (0.010)	0.46 (0.11)	1.37 (0.05)	2.50 (3.3)
Silt loam	0.067 (0.015)	0.45 (0.08)	1.41 (0.12)	4.50 (12.3)
Sandy clay loam	0.100 (0.006)	0.39 (0.07)	1.48 (0.13)	13.10 (27.4)
Clay loam	0.095 (0.010)	0.41 (0.09)	1.31 (0.09)	2.60 (7.0)
Silty clay loam	0.089 (0.009)	0.43 (0.07)	1.23 (0.06)	0.70 (1.9)
Sandy clay	0.100 (0.013)	0.38 (0.05)	1.23 (0.10)	1.20 (2.8)
Silty clay	0.070 (0.023)	0.36 (0.07)	1.09 (0.06)	0.20 (1.1)
Clay	0.068 (0.034)	0.38 (0.09)	1.09 (0.09)	2.00 (4.2)

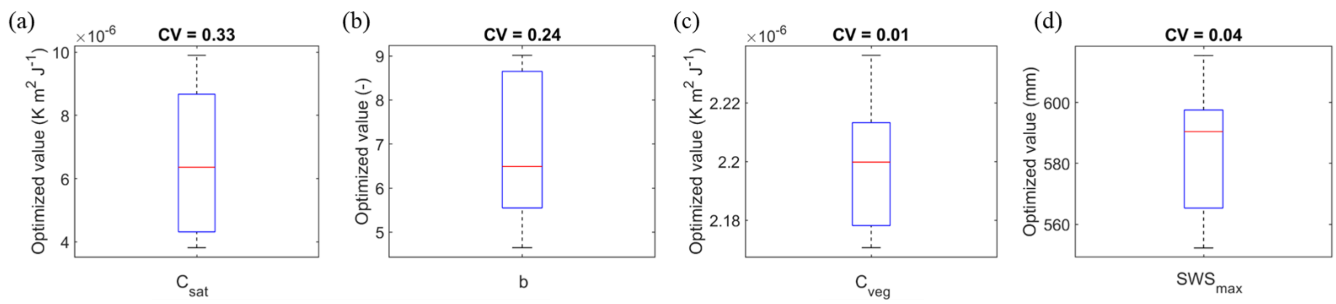

Figure S1. Boxplots of the best ten parameter values from the Pareto front analysis. CV refers the coefficient of variation (mean/standard deviations).

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