Toward a better representation of soil evaporation in ORCHIDEE

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INTERN, UMR-METIS

Bare Soil Evaporation (BSE) in literature

Type of formulation	Study	formulation
$E_{soil} = \rho_a \, \beta [q_s(T_s) - q_a]$	**ORCHIDEE (11 layer)**	$\beta = Corrfac. \frac{1}{r_a}$
	Sellers et al, 1992	$\beta = \frac{1}{r_{soil}+r_a}, \quad r_{soil} = e^{8.206-4.255 \frac{\theta_1-\theta_r}{\theta_s-\theta_r}}$
	Best. et al, 2011	$\beta = \frac{1}{r_{soil}+r_a} \quad r_{soil} = 100 \, (\frac{\theta_c}{\theta_1})^2$
$E_{soil} = \rho_a \, \beta \, [\boldsymbol{\alpha} \, q_s(T_s) - q_a]$ $\alpha = h_u = exp\left(\frac{g.\psi(\theta_1)}{R.T_1}\right)$	**SiSPAT**	$\beta = \frac{1}{r_a}$
	Sakaguchi and Zeng, 2009	$\beta = \frac{1}{r_{soil}+r_a+r_{litter}}, \quad r_{soil} = \frac{L}{D}$ $L = d_1 \frac{\exp\left[(1-\frac{\theta_1}{\theta_{sat}})^w\right]-1}{e-1}$ *(dry layer thickness)* $D = D_0 \theta_{sat}^2 \left(1 - \frac{\theta_r}{\theta_{sat}}\right)^{2+3b}$ *(reduced diffusivity)* $r_{litter} = \frac{1}{0.004. u_*}(1 - e^{-L_{litter}}),$
	Tang and Riley, 2013	$\beta = \frac{1}{r_{soil} + r_a}, \quad r_{soil} = \frac{\Delta z_1}{2\mu\theta_1 D_w + 2\varepsilon D_g}$

- 1^{st} : Simplified ORCHIDEE in R platform

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  - Limitations and assumptions

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    - Soil classes

Soil Class	**Saturated Conductivity K ($m.s^{-1}$)**
Clay	1.7E-07
Clay Loam	6.4E-07
Loam	3.7E-06
Loamy Sand	1.7E-05
Silt	6.9E-07
Silty Loam	1.9E-06
Silty Clay	2.5E-07
Silty Clay Loam	4.2E-07
Sand	5.8E-05
Sandy Cly	3.3E-07
Sandy Clay Loam	1.2E-06
Sandy Loam	1.0E-05

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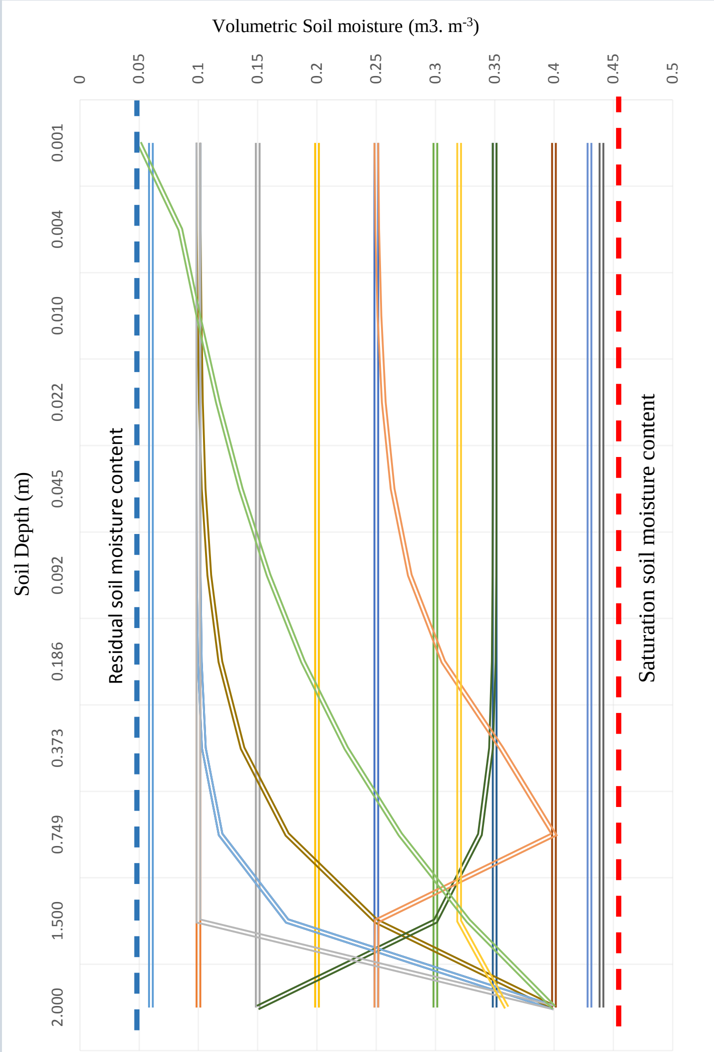
    - Soil moisture profiles



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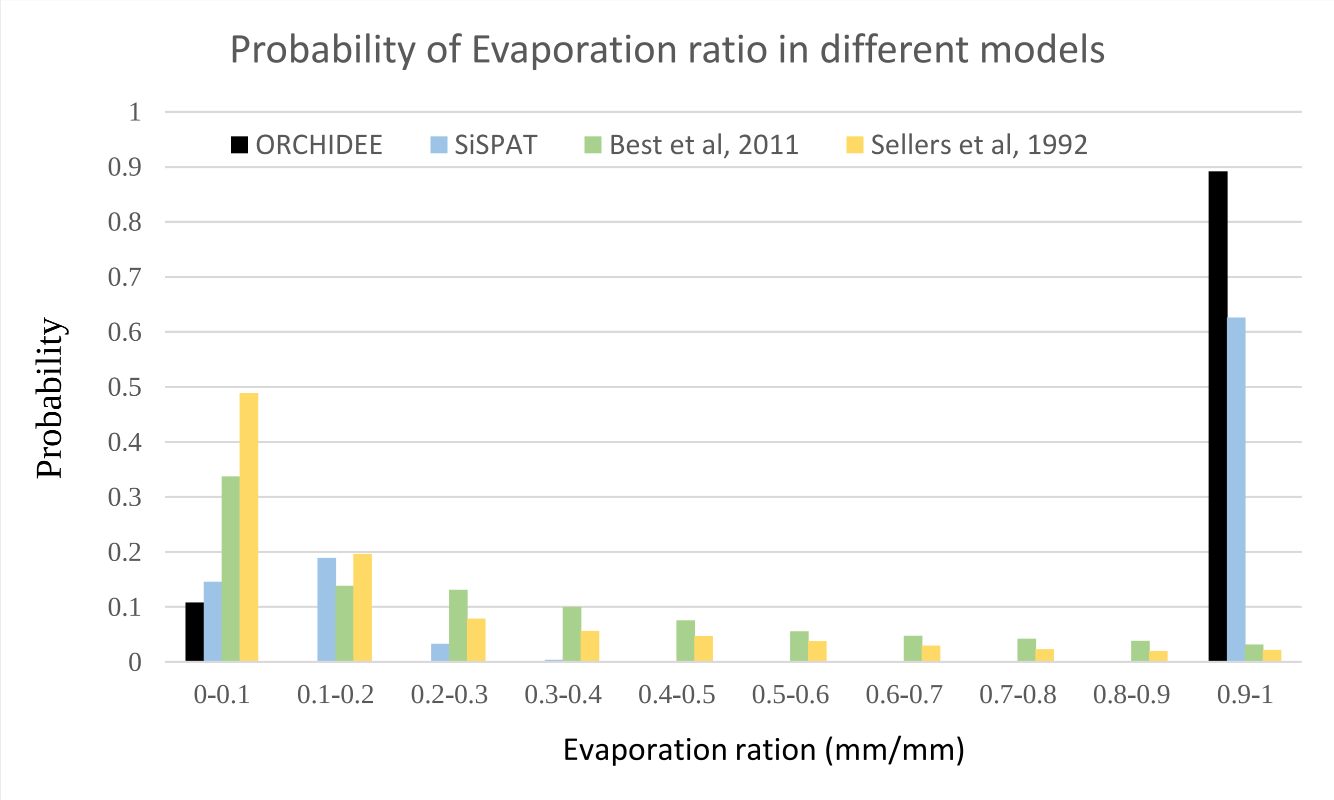

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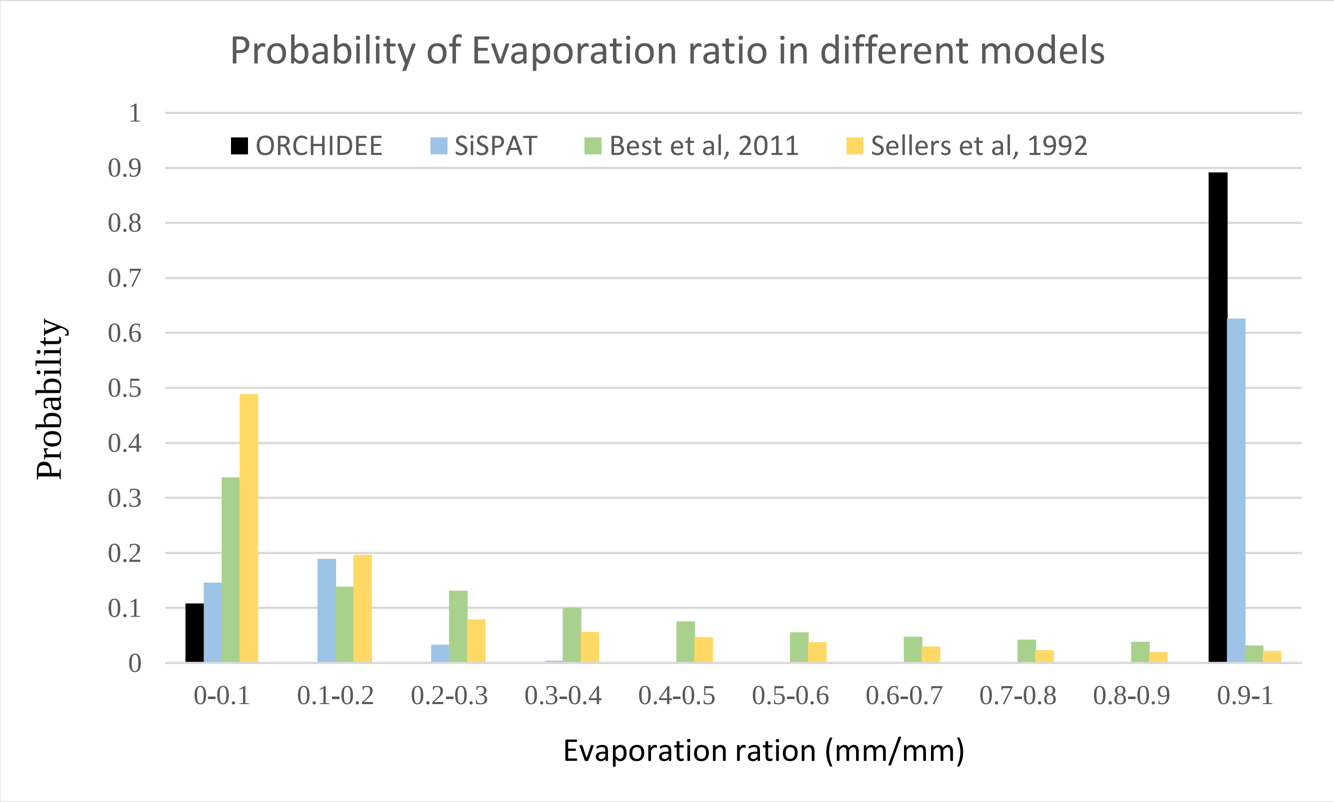

Evaploration ratio	ORCHIDEE		SiSPAT		Best et al, 2011		Sellers et al, 1992	
	Regular	Dirichlet	Regular	Dirichlet	Regular	Dirichlet	Regular	Dirichlet
0-0.1	0	10.8	0	14.6	34	0	46.6	2.2
0.1-0.2	0	0	0	18.9	13.9	0	18.6	1.0
0.2-0.3	0	0	0	3	13.1	0	7.9	0
0.3-0.4	0	0	0	0	10.0	0	5.6	0
0.4-0.5	0	0	0	0	7.6	0	4.7	0
0.5-0.6	0	0	0	0	5.6	0	3.8	0
0.6-0.7	0	0	0	0	4.8	0	3.0	0
0.7-0.8	0	0	0	0	4.2	0	2.3	0
0.8-0.9	0	0	0	0	3.8	0	2.0	0
0.9-1	89.2	0	62.6	0	3.2	0	2.2	0
Total	89	11	63	37	100	0	97	3

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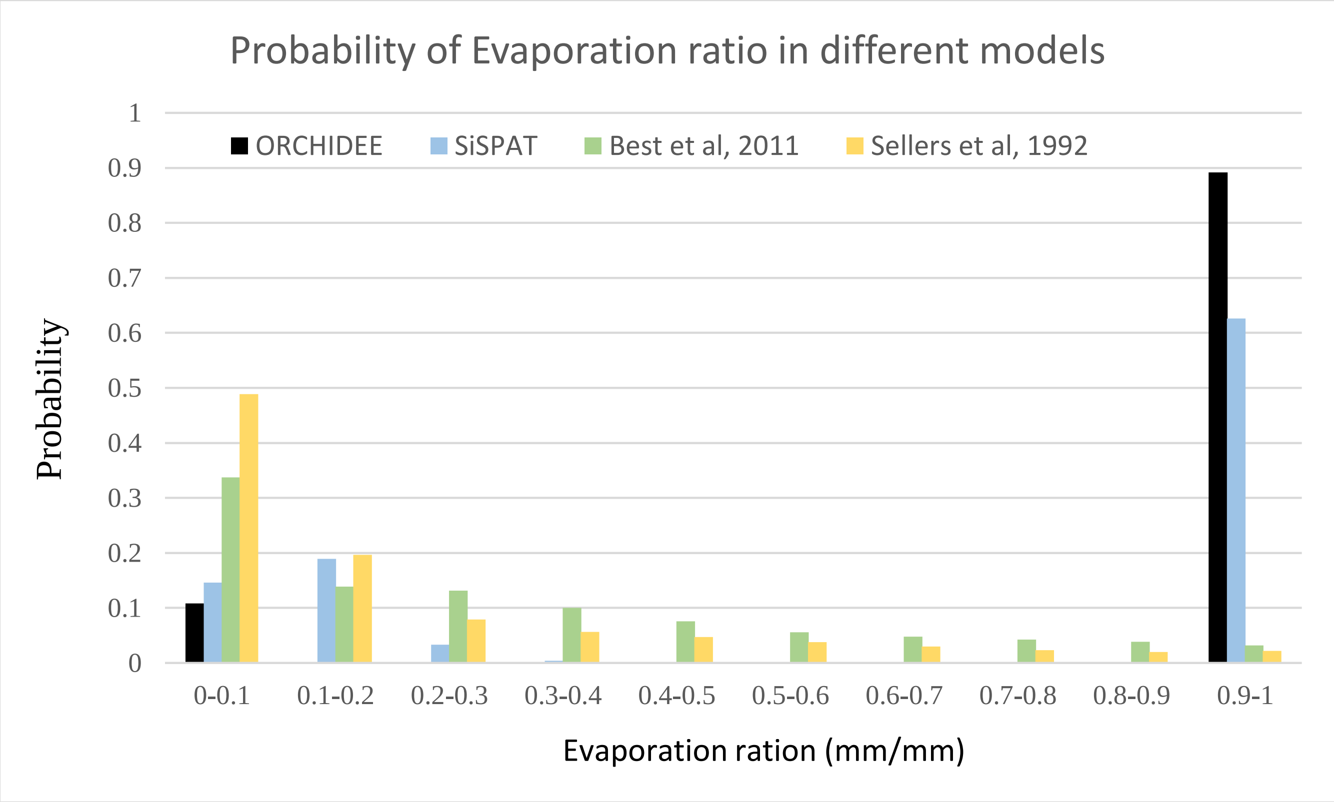

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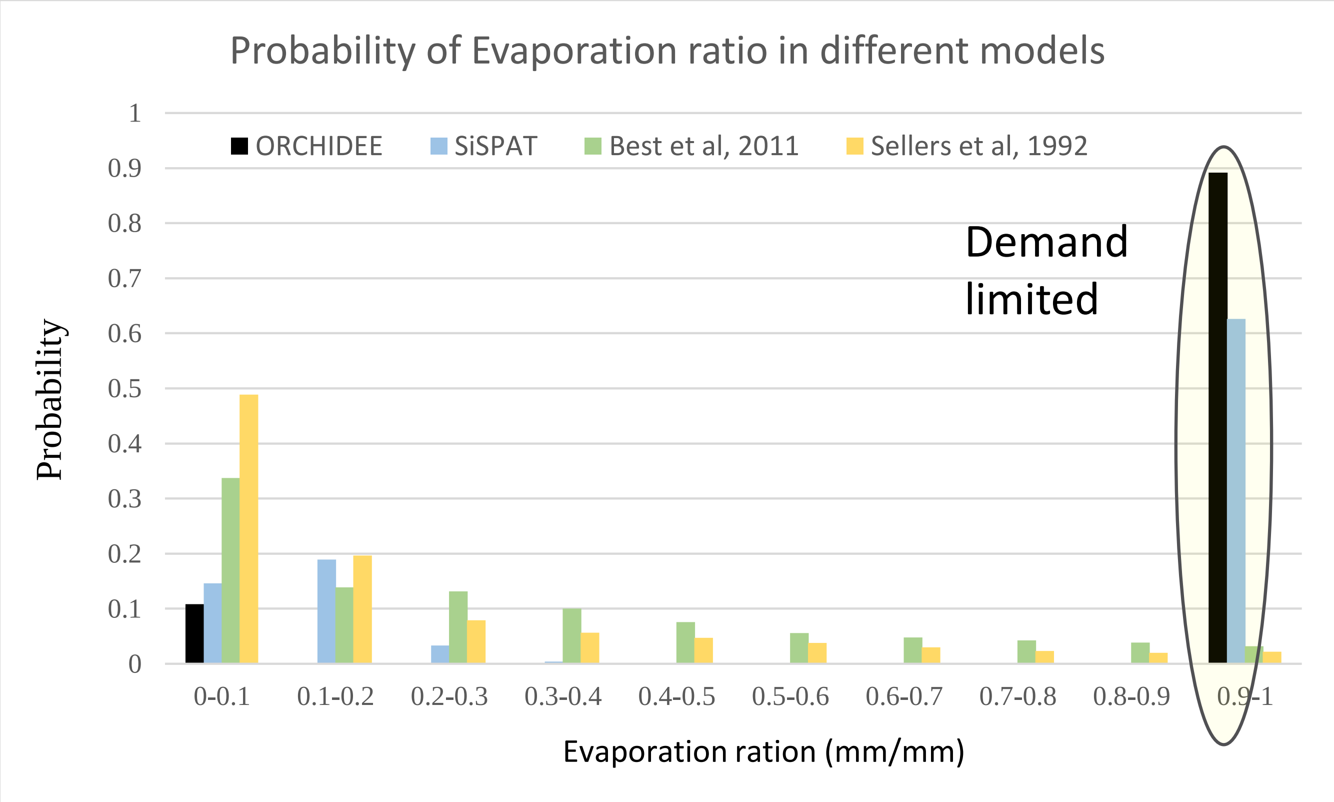

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0.3-0.4	0	0	0	0	10.0	0	5.6	0
0.4-0.5	0	0	0	0	7.6	0	4.7	0
0.5-0.6	0	0	0	0	5.6	0	3.8	0
0.6-0.7	0	0	0	0	4.8	0	3.0	0
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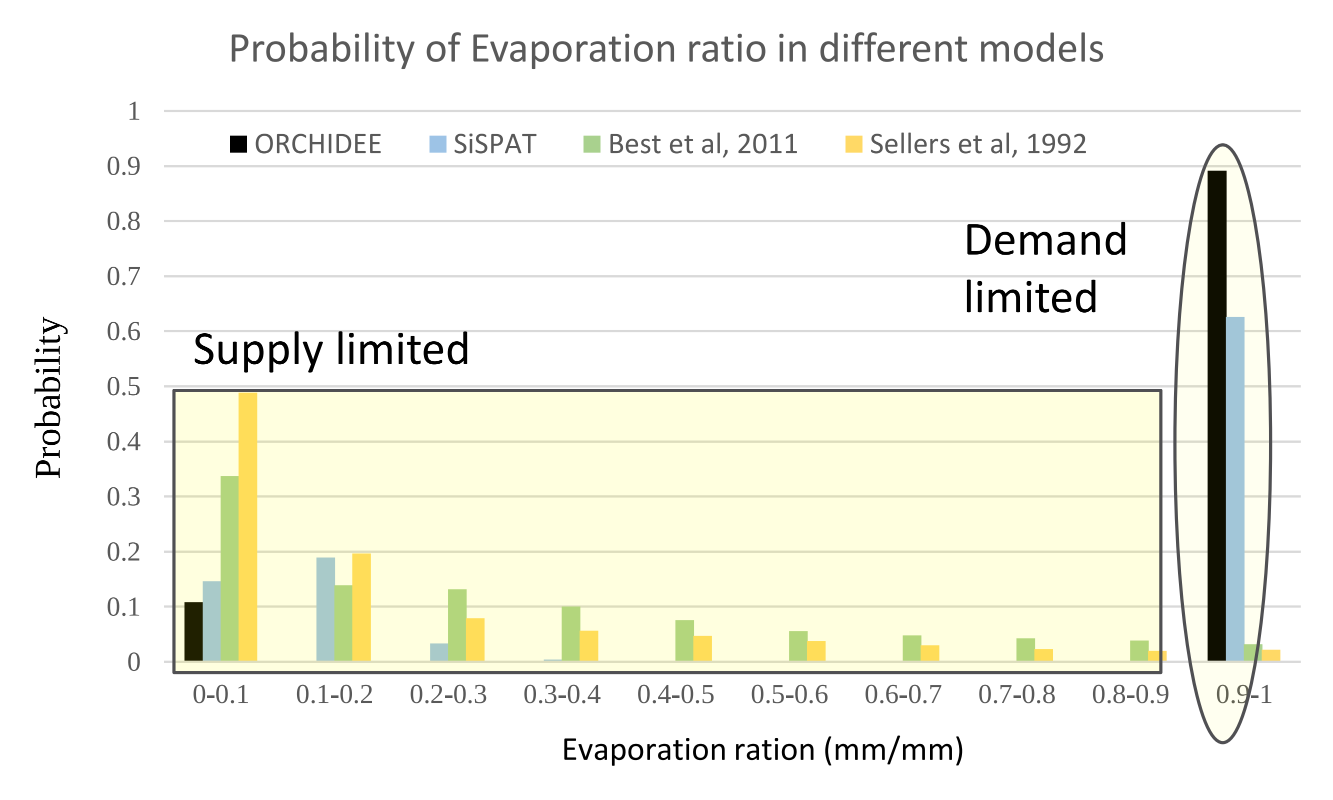

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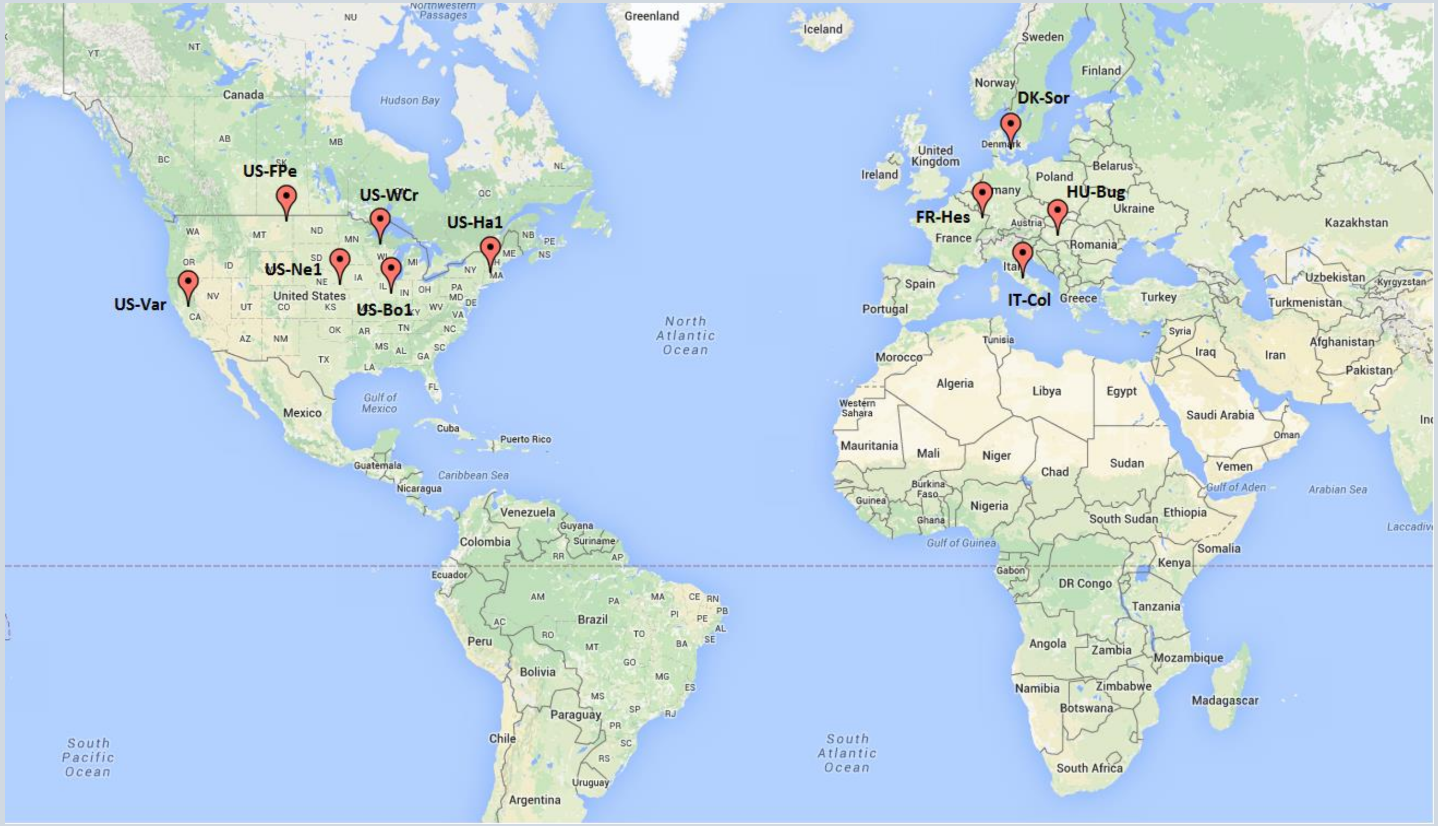

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  - Length and continuity

Fluxnet ID	Country	Coordinate		Year of data availability																								
		Latitude	Longitude	1991	1991	1991	1991	1991	1991	1991	1991	1991	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
US-Bo1	Illinois, USA	40.0062	-88.2904																									
HU-Bug	Hungary	46.6911	19.6013																									
IT-Col	Italy	41.8494	13.5881																									
US-FPe	Montana, USA	48.3077	-105.1019																									
US-Ha1	Massachusetts, USA	42.5378	-72.1715																									
FR-Hes	France	48.6742	7.0656																									
US-Ne1	Nebraska, USA	41.1651	-96.4766																									
DK-Sor	Denmark	55.4859	11.6446																									
US-Var	California, USA	38.4067	-120.9507																									
US-WCr	Wisconsin, USA	45.8059	-90.0799																									

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Forest

Grassland

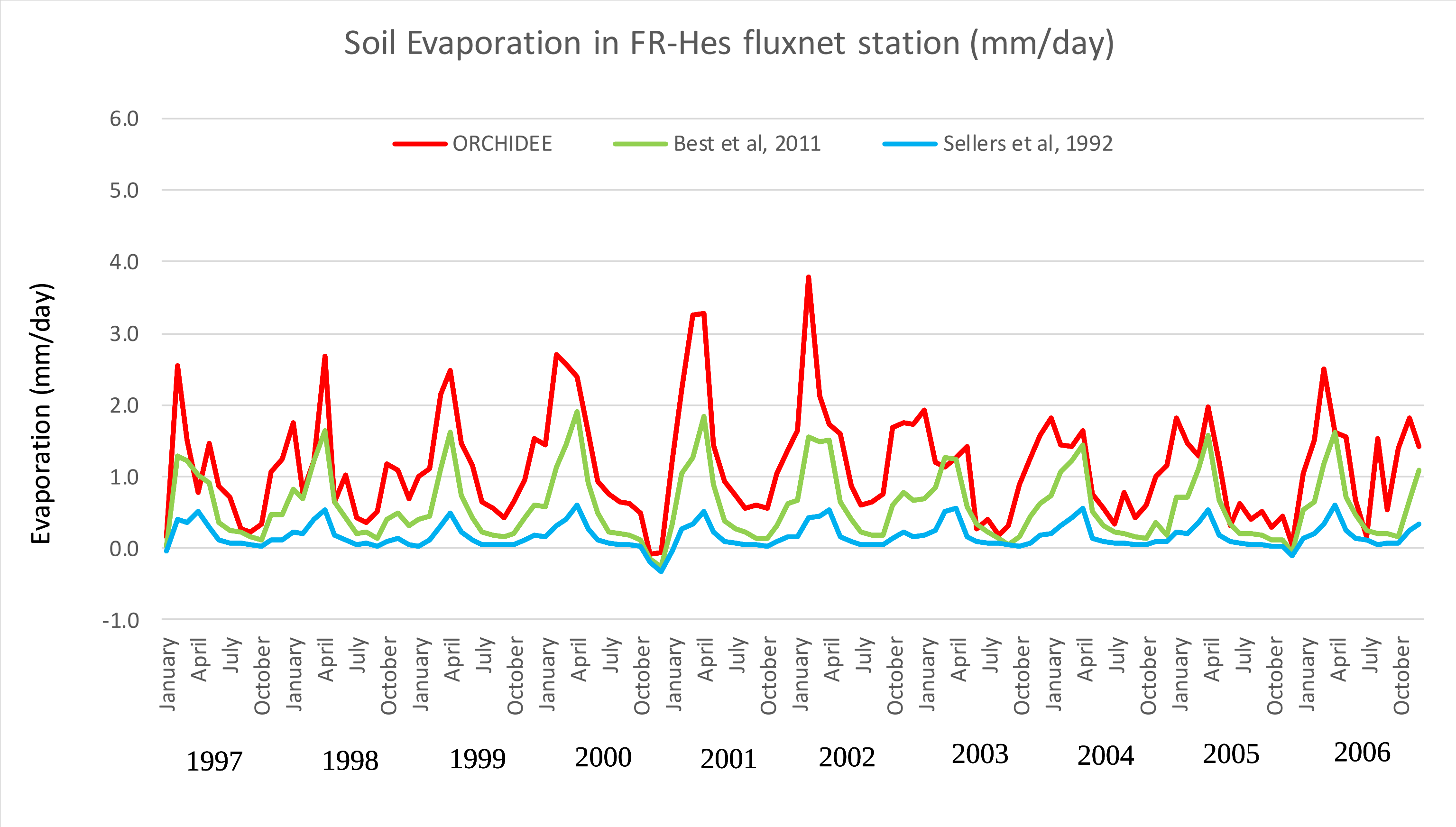
- 2^{nd}: Testing ORCHIDEE at FLUXNET stations
  - Two formulas for BSE calculation

Type	Reference	Formulation
Standard ORCHIDEE (11 layer)	Several references of the ORCHIDEE team	$E_{soil} = \rho_a \frac{1}{r_a}[q_s(T_w) - q_a]$
Resistance terms	Best et al, 2011	$E_{soil} = \rho_a \frac{1}{r_a + r_s}[q_s(T_s) - q_a]$ $r_s = 100 (\frac{\theta_c}{\theta_1})^2$
	Sellers et al, 1992	$E_{soil} = \rho_a \frac{1}{r_a + r_s}[q_s(T_s) - q_a]$ $r_s = e^{8.206-4.255 \frac{\theta_1-\theta_r}{\theta_s-\theta_r}}$

• 2nd: Testing ORCHIDEE at FLUXNET stations

Forest site

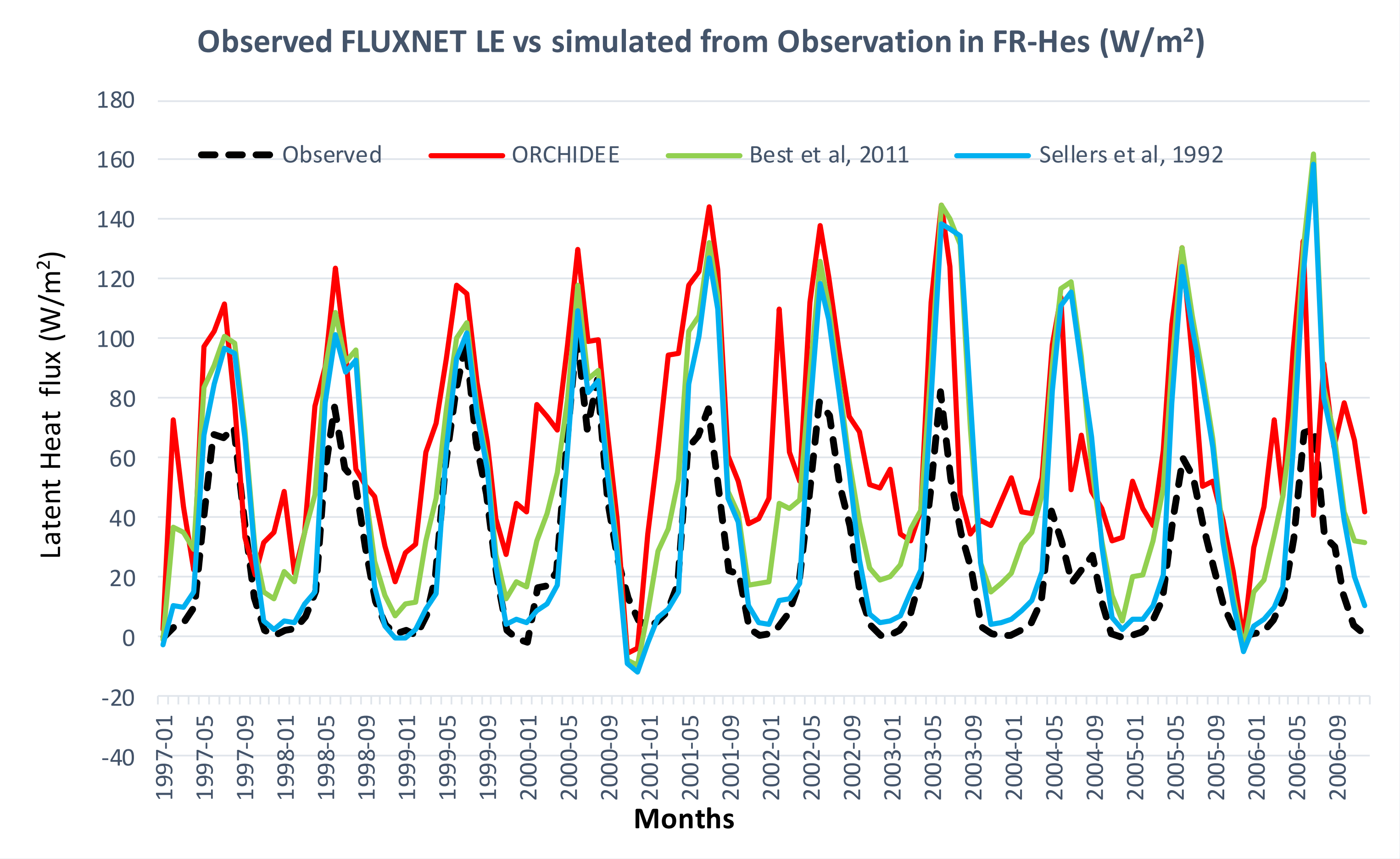
Soil Evaporation



- 2nd: Testing ORCHIDEE at FLUXNET stations

Forest site

Latent Heat Flux



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Forest site

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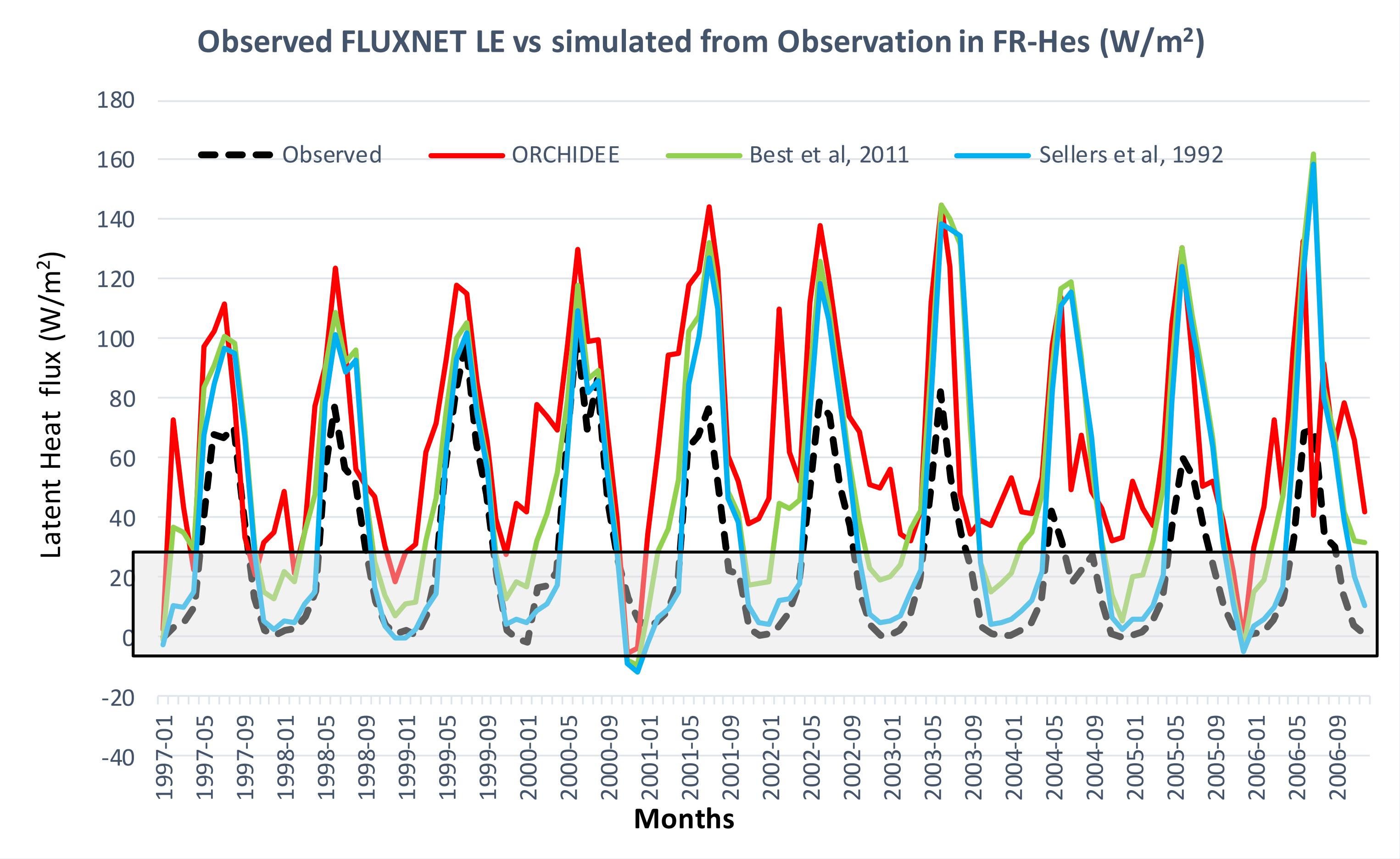

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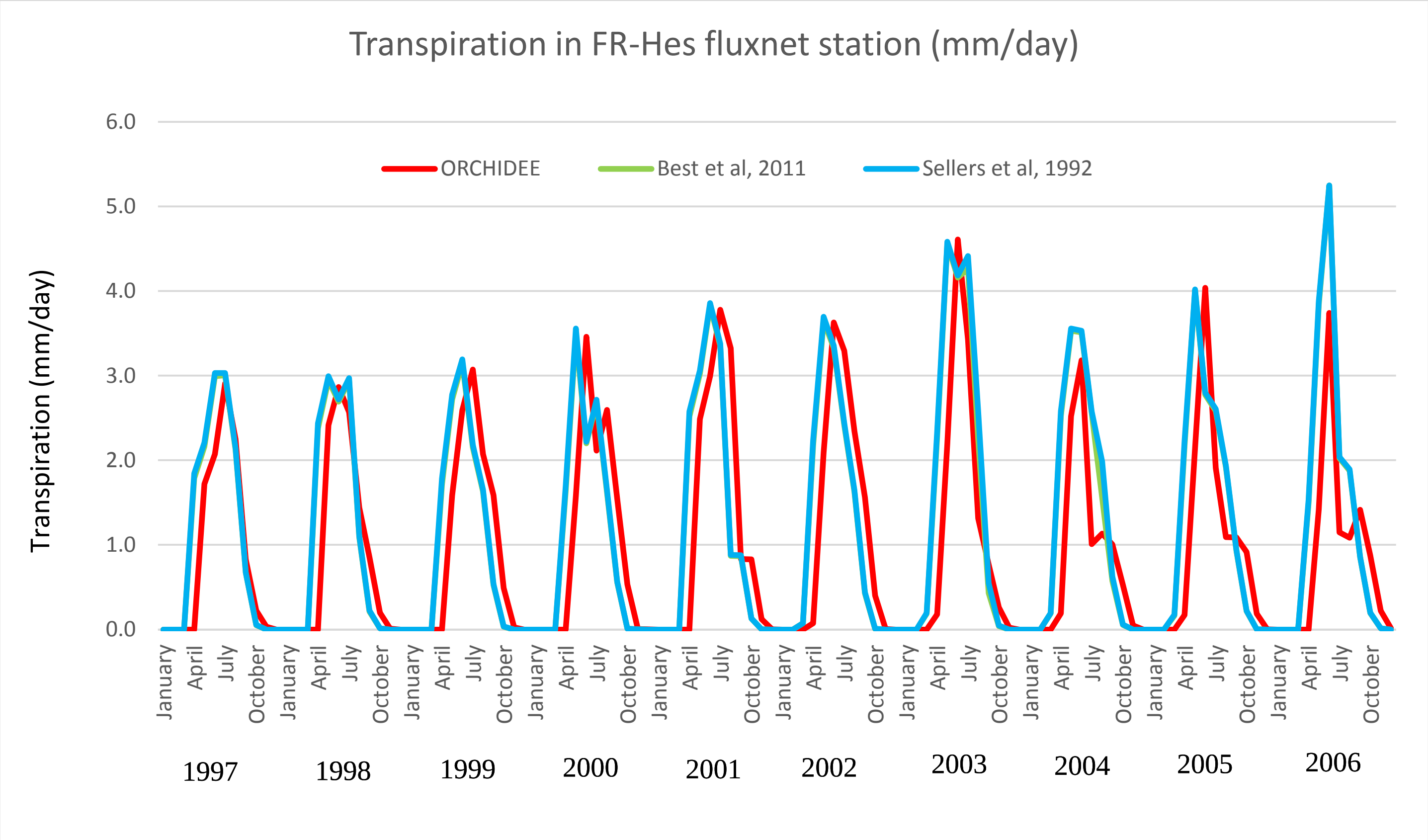


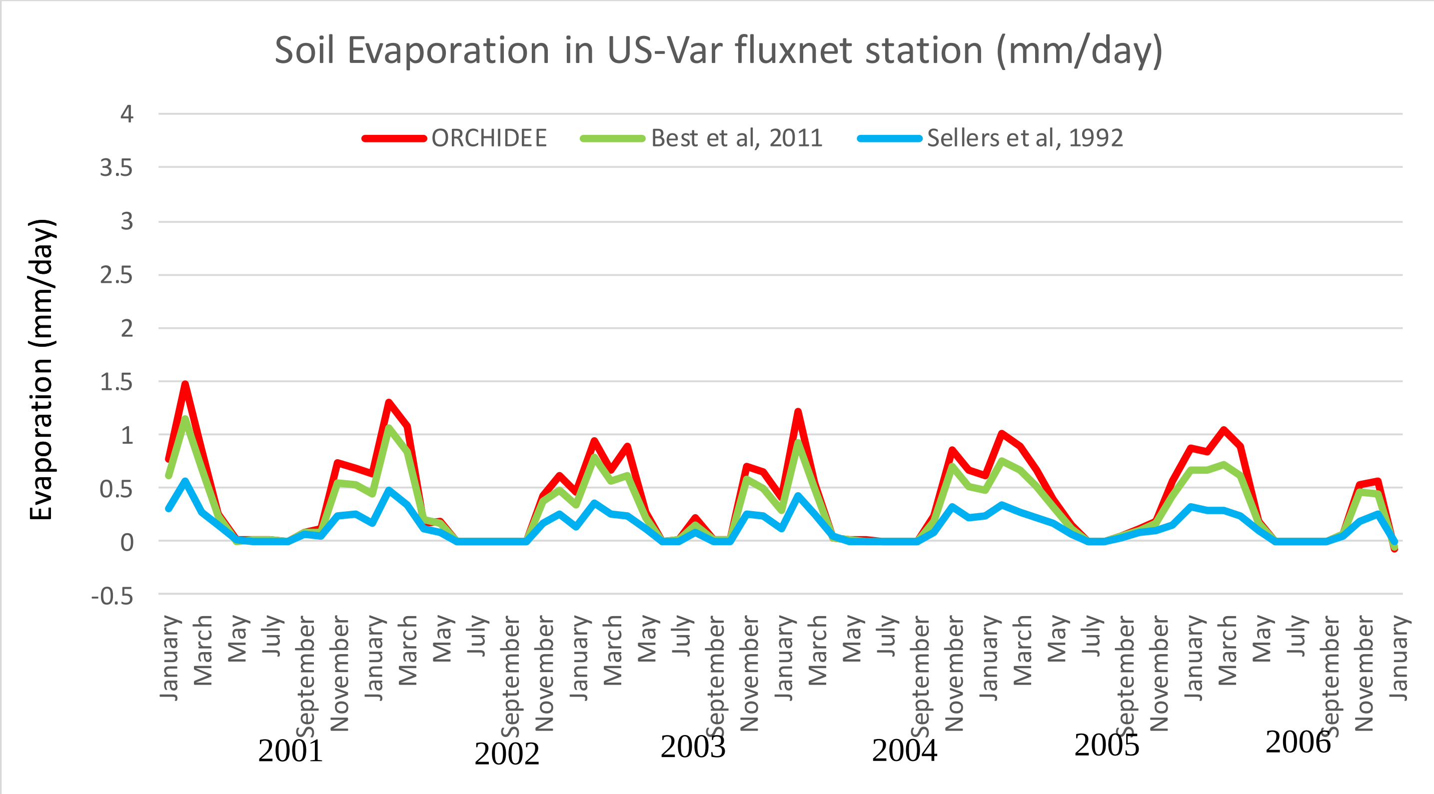
Forest site

Transpiration

- 2nd: Testing ORCHIDEE at FLUXNET stations

Grassland site

Soil Evaporation



Grassland site

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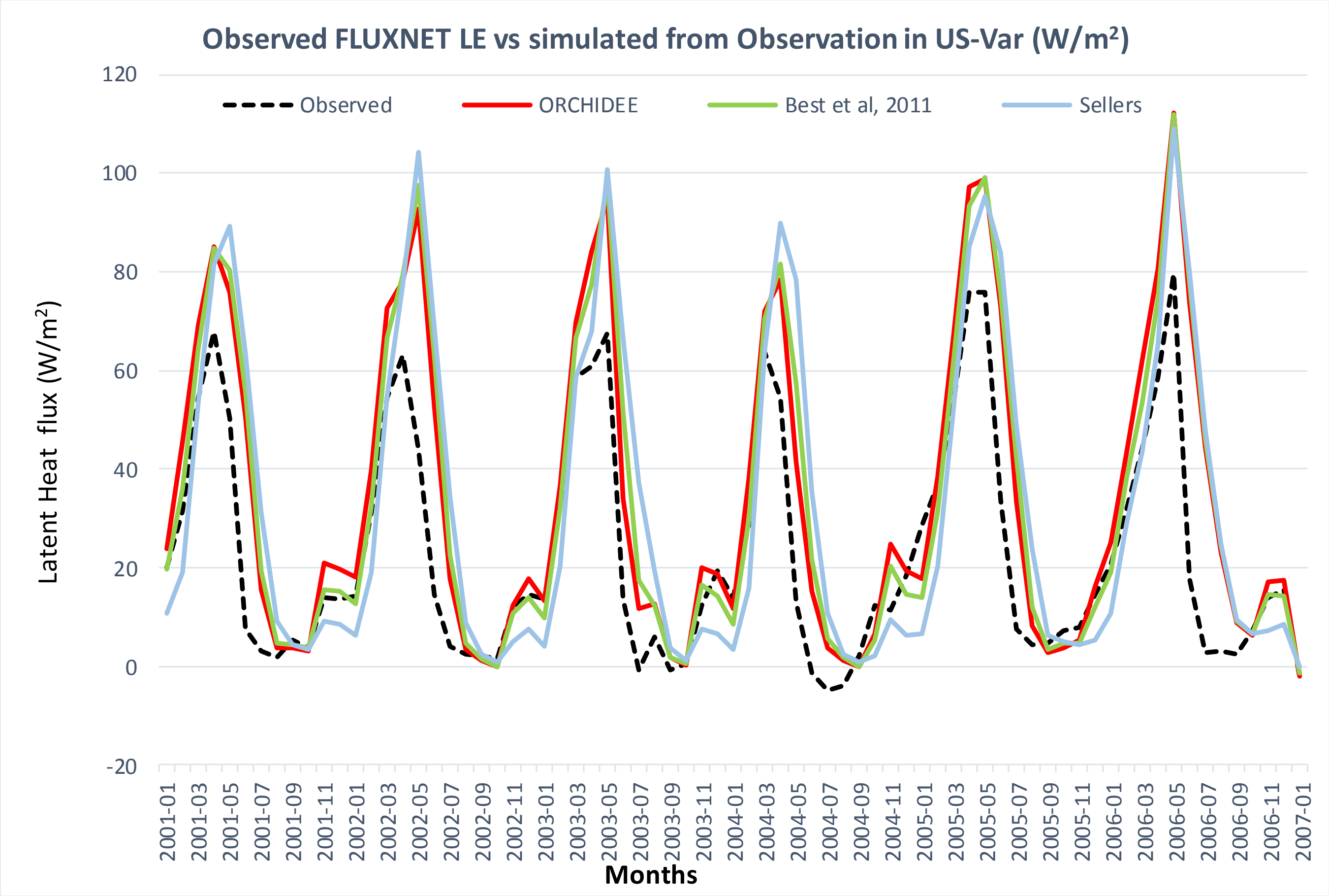

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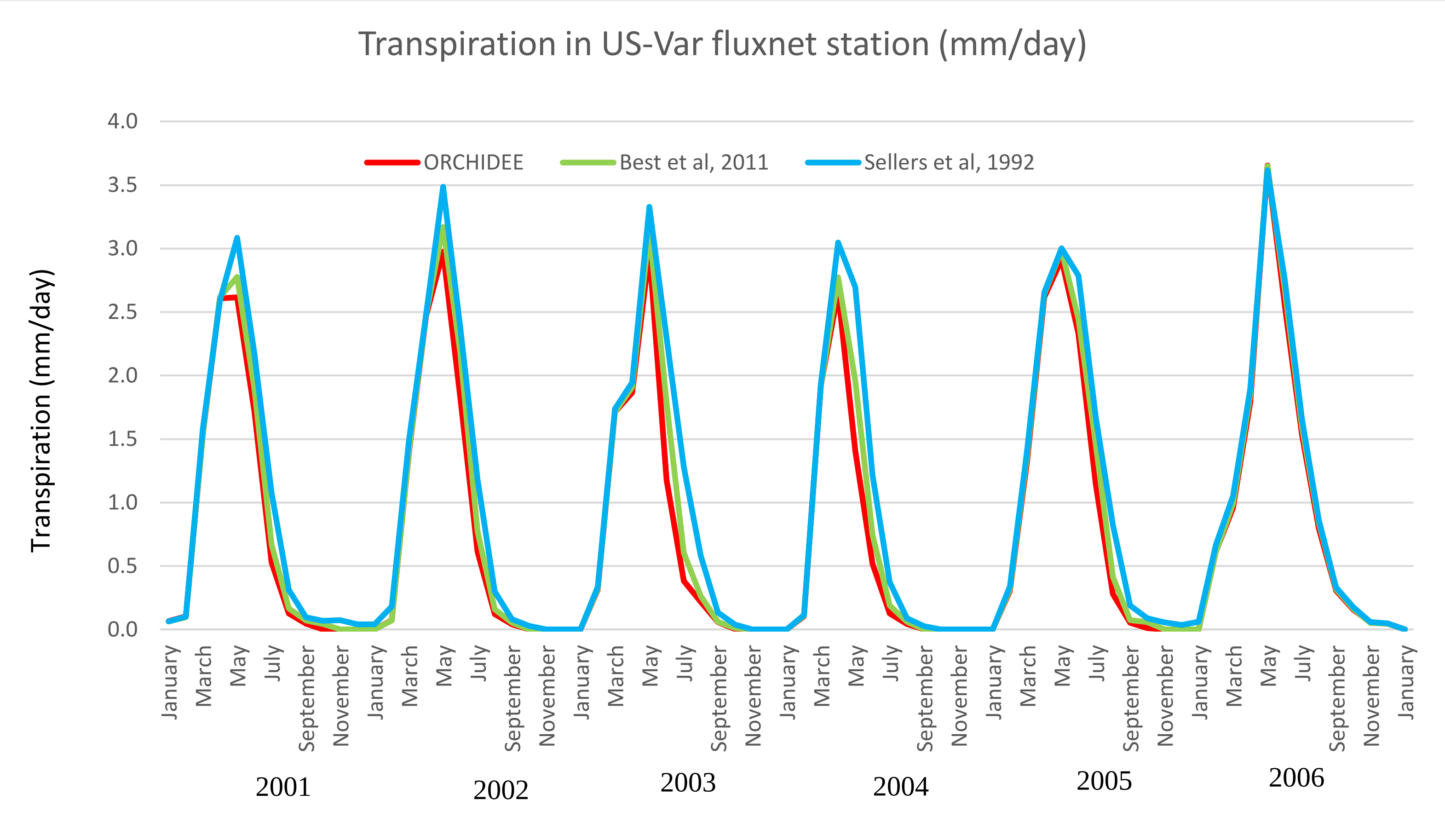

• 2nd: Testing ORCHIDEE at FLUXNET stations

Winter

irrigated

PFT	Station	Winter LE Fluxnet observation ($W/m^2.s$)	LE winter bias ($W/m^2.s$)		
			ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	2.3	36.6	8.8	-1.0
	FR-Hes	1.8	52.9	17.1	2.4
	IT-Col	2.8	2.5	-1.3	-4.7
	US-WCr	1.8	25.0	16.4	9.6
	US-Ha1	7.4	4.6	-3.4	-11.9
Cropland C4	US-Ne1	10.2	2.4	1.8	0.3
	US-Bo1	16.0	38.7	33.1	21.2
Grassland C3	HU-Bug	6.2	-4.0	-4.5	-7.4
	US-Fpe	3.6	3.4	-1.6	-10.0
	US-Var	21.2	19.7	17.3	13.5

Improved	(green)
Deteriorated	(yellow)

Summer

irrigated

PFT	Station	Summer LE Fluxnet observation ($W/m^2.s$)	LE summer bias ($W/m^2.s$)		
			ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	71.4	23.8	13.9	8.5
	FR-Hes	61.8	39.7	47.8	43.2
	IT-Col	56.8	1.7	8.8	12.1
	US-WCr	74.5	51.2	44.7	40.0
	US-Ha1	71.2	0.6	8.2	8.6
Cropland C4	US-Ne1	111.1	-4.7	-2.6	2.5
	US-Bo1	90.9	30.4	24.7	18.7
Grassland C3	HU-Bug	63.8	-7.0	-4.0	-0.3
	US-Fpe	55.2	20.4	24.8	32.5
	US-Var	6.2	15.8	8.6	0.9

Latent heat flux bias

• 2nd: Testing ORCHIDEE at FLUXNET stations

Relative bias(%)= $\frac{Simulation - observed}{observed} \times 100$

Latent heat flux relative bias

Improved	(green)
Deteriorated	(yellow)

Winter

PFT	Station	relative bias (%) winter		
		ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	1563	374	-42
	FR-Hes	3007	973	139
	IT-Col	887	581	340
	US-WCr	1074	942	733
	US-Ha1	523	446	287
Cropland C4 (irrigated → US-Ne1)	US-Ne1	-39	-44	-73
	US-Bo1	29	-21	-75
Grassland C3	HU-Bug	40	-20	-75
	US-Fpe	65	49	10
	US-Var	16	-7	-47

Summer

PFT	Station	relative bias (%) summer		
		ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	33	19	12
	FR-Hes	64	77	70
	IT-Col	90	79	70
	US-WCr	21	12	1
	US-Ha1	43	35	26
Cropland C4 (irrigated → US-Ne1)	US-Ne1	-6	-4	0
	US-Bo1	1	9	9
Grassland C3	HU-Bug	3	14	19
	US-Fpe	-9	-5	5
	US-Var	328	400	523

- 2nd: Testing ORCHIDEE at FLUXNET stations

Winter

irrigated → US-Ne1

PFT	Station	LE RMSE (Fluxnet vs simulated) winter		
		ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	40.6	11.7	6.5
	FR-Hes	97.9	21.1	6.1
	IT-Col	28.2	20.3	15.5
	US-WCr	22.4	20.2	17.2
	US-Ha1	41.6	36.6	29.1
Cropland C4	US-Ne1	4.6	4.8	7.8
	US-Bo1	8.8	7.6	14.1
Grassland C3	HU-Bug	7.7	5.1	5.5
	US-Fpe	5.9	5.3	4.9
	US-Var	6.2	4.7	11.2

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Deteriorated	(yellow)

Summer

irrigated → US-Ne1

PFT	Station	LE RMSE (Fluxnet vs simulated) summer		
		ORCHIDEE	Best et al, 2011	Sellers et al, 1992
Temperate deciduous broadleaf forest	DK-Sor	33.6	24.8	23.1
	FR-Hes	46.7	54.9	51.2
	IT-Col	57.2	51.8	48.4
	US-WCr	32.0	28.9	33.2
	US-Ha1	38.7	32.5	27.8
Cropland C4	US-Ne1	40.4	38.7	37.2
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Latent heat flux root mean square error

In this study we found out:

- Resistance terms improves forests' winter time latent heat simulation
- Using α (relative humidity) in formulation: No effect if $\psi \succ 100\ (m)$
- Rootsink activation: no significant effect
- Latent heat flux is still higher than observation (summer time)
- Increased transpiration in summer
- Importance of FLUXNET station selection for validation