Sensitivity Analysis of ORCHIDEE

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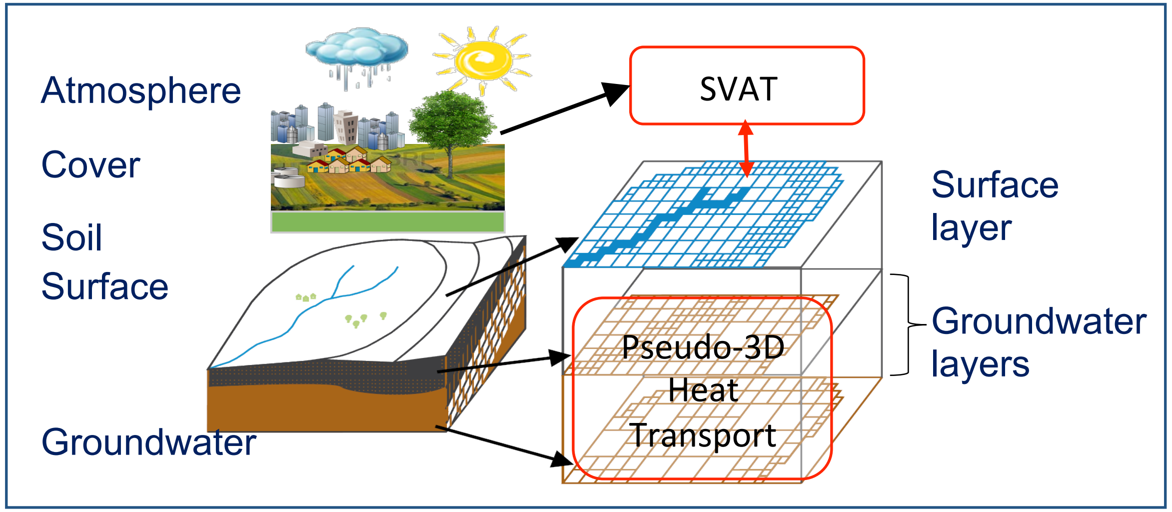
Introduction

- Context:
  - Understand the evolution of the temperature in all components of the hydrosystem
- Heat fluxes
  - Marker of climate change
  - Greatly influences:
    - Dissolved organic matter (DOM) solubility; hence saturation point & content.
    - Solubility of other gases and solutes (weathering)
    - Speed of chemical and biological reactions.
    - Biological populations (directly and indirectly)
  - An integral part of the toolbox used to investigate water flow
    - Heat as a tracer of the flow
- Complex physical interactions between land-surface and subsurface processes make accurate simulations of water and energy fluxes (especially recharge) a challenging task

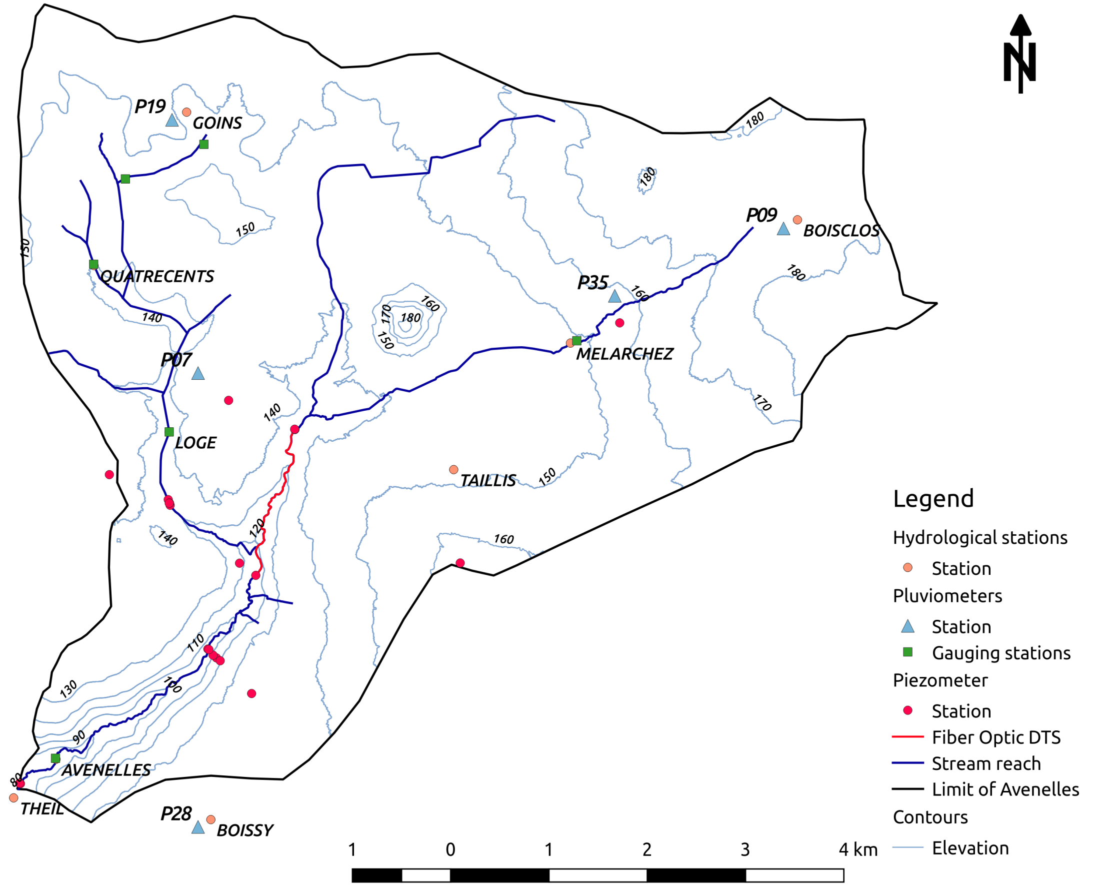
Introduction

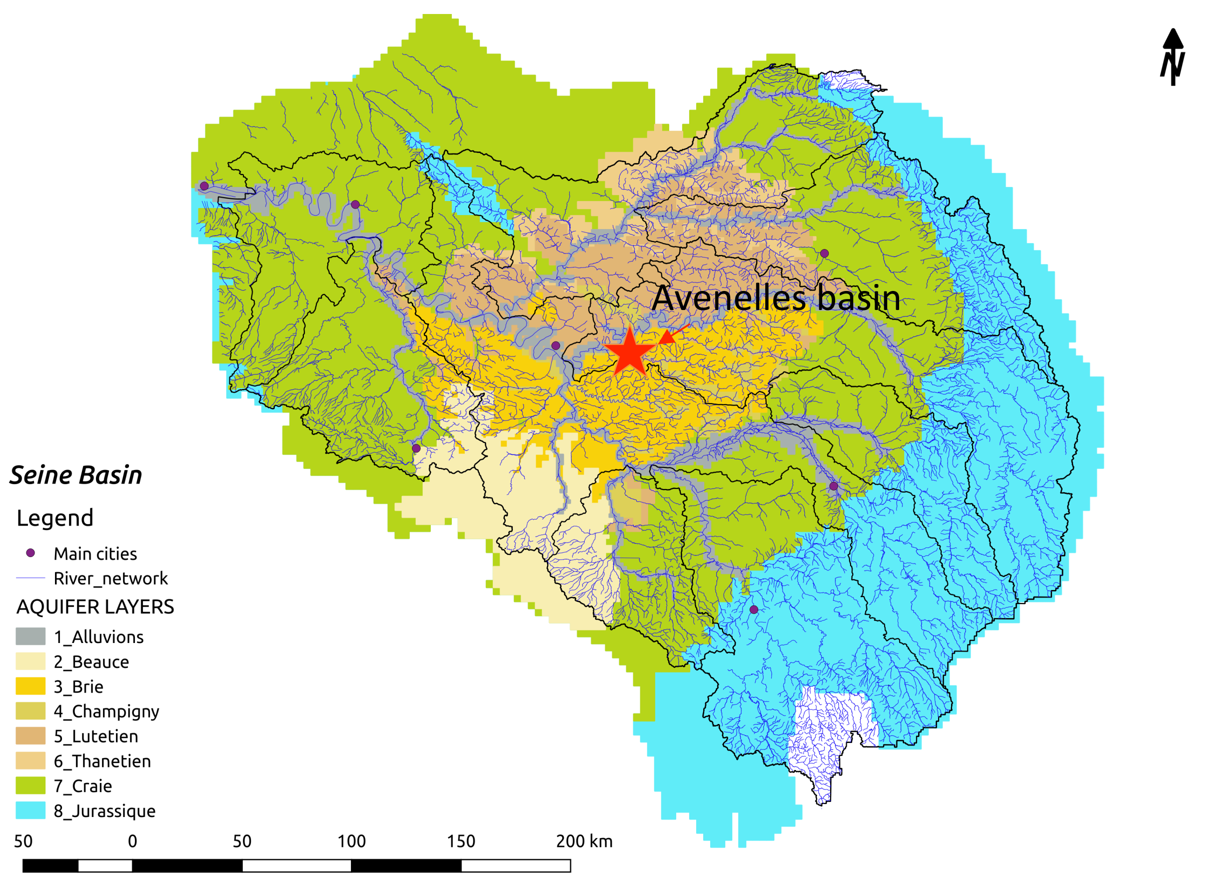
- Methodology:
  - Integrated model by coupling a SVAT model (ORCHIDEE) and pseudo-3D distributed hydrological model CAWAQS to accurately simulate hydrosystem processes



  - Sensibility analysis to be able to calibrate the model
  - A sensitivity analysis framework is developed by taking advantage of Morris screening test and empirical orthogonal functions (EOF)

Study sites

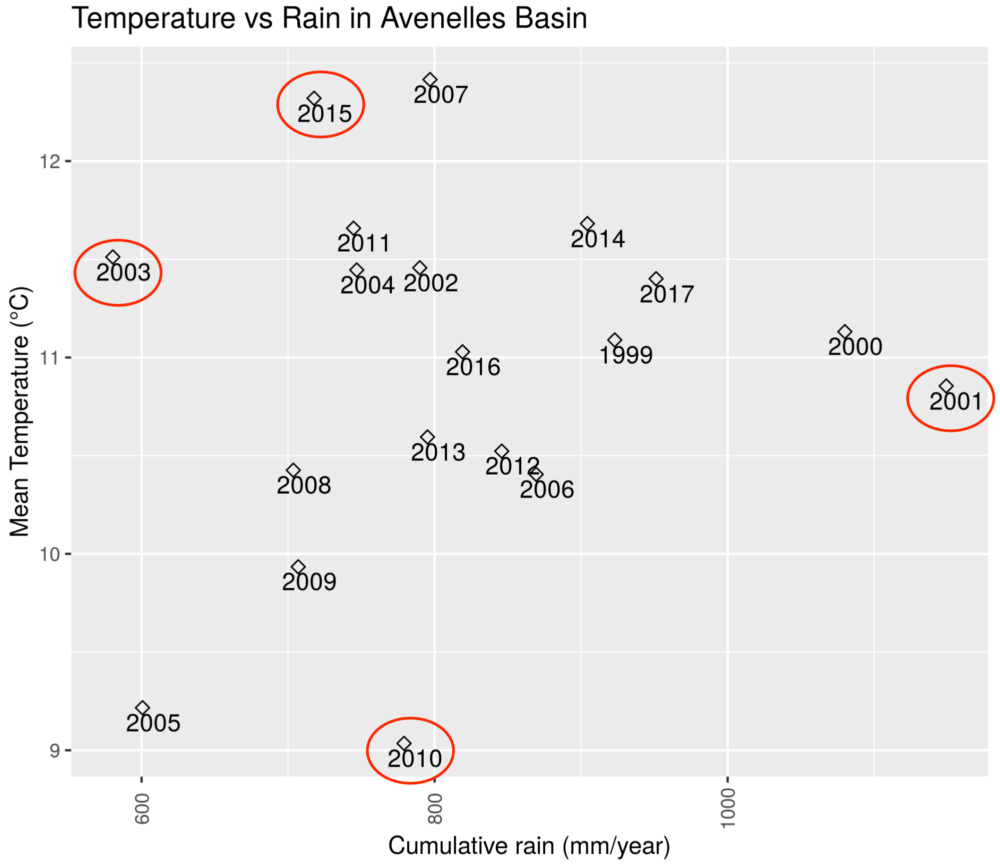


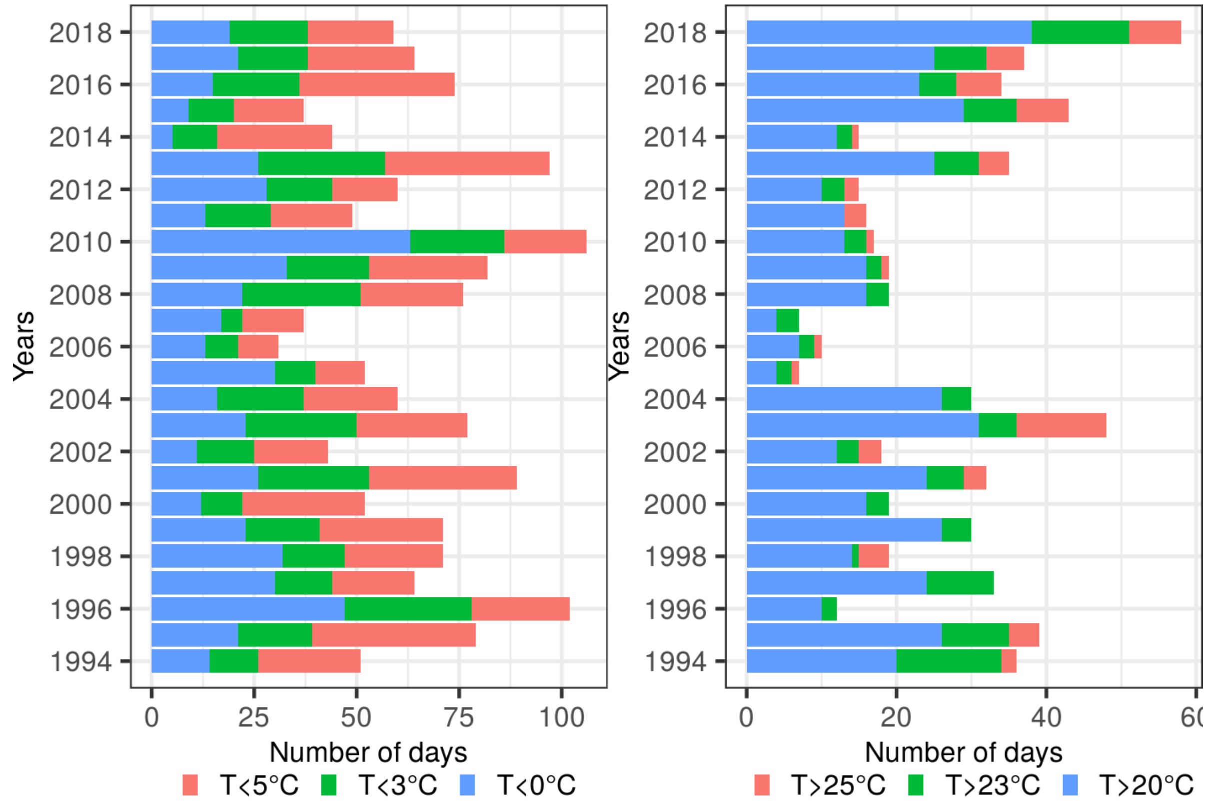


- Small catchment (46km^2)
- Experimental basin
- Proof-of-concept with ORCHIDEE + CAWAQS
- Underlain by Champigny and Brie aquifers
- 80% C3 agricultural crop, 17% Forest

- Large catchment (~76000km^2)
- Application basin
- Application with ORCHIDEE + CAWAQS coupled
- Underlain by Beauce, Brie, Champigny, Lutetien, Thanetien, Craie, and Jurassic aquifers

Experimental setup & methodology





Extreme weather scenarios are selected to test model behavior under different hydrological states:

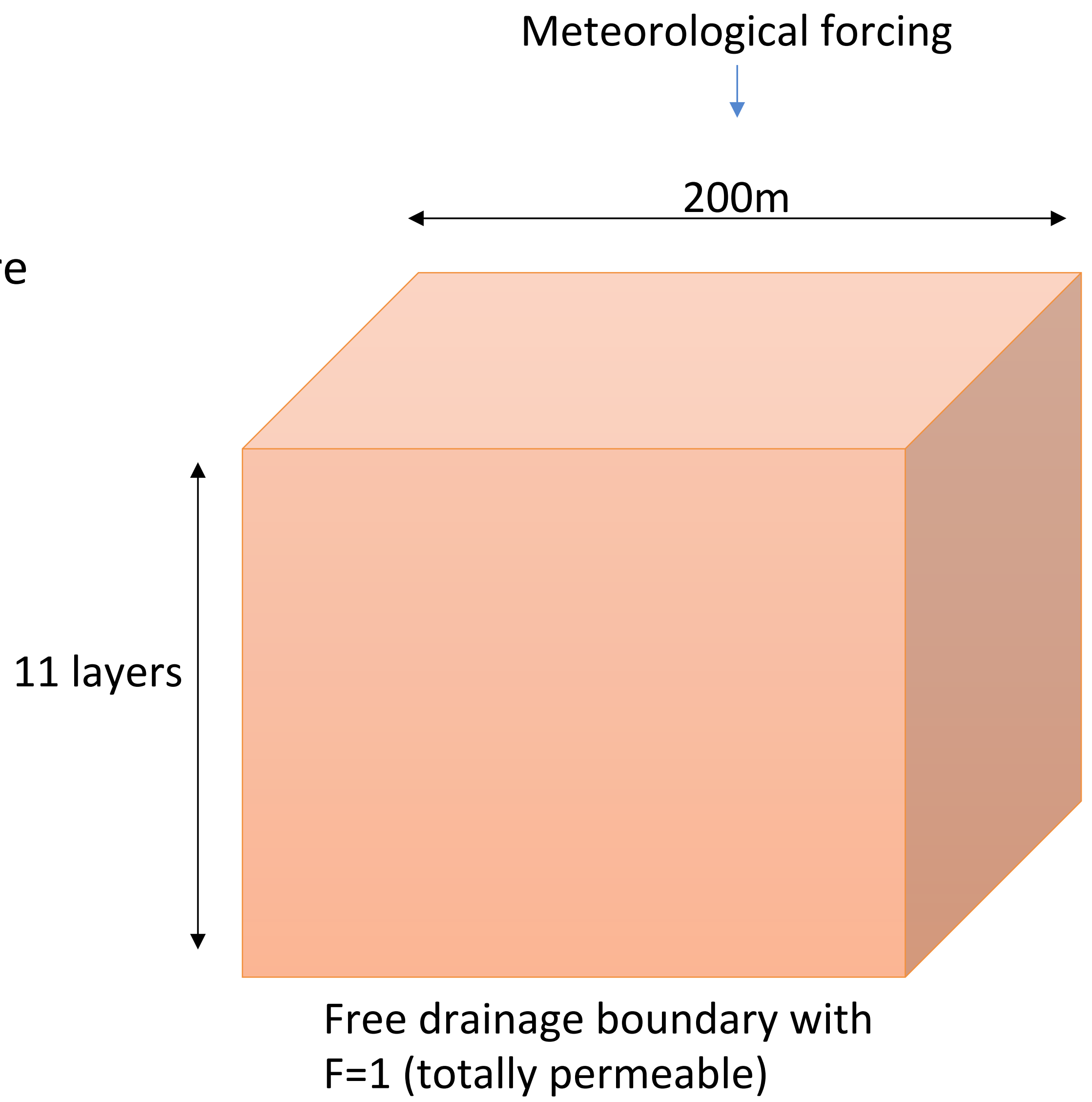
- Dry year (2003)
- Wet year (2001)
- Hot year (2015)
- Cold year (2010)

Sensitivity analysis methodology : Numerical setup

- A single grid (1D) using ORCHIDEE_2_2 is generated
- STOMATE activated
- Homogeneous soil is described
- Bare soil (PFT 1), C3 type agricultural crop (PFT 12) are described

Meteorological forcing

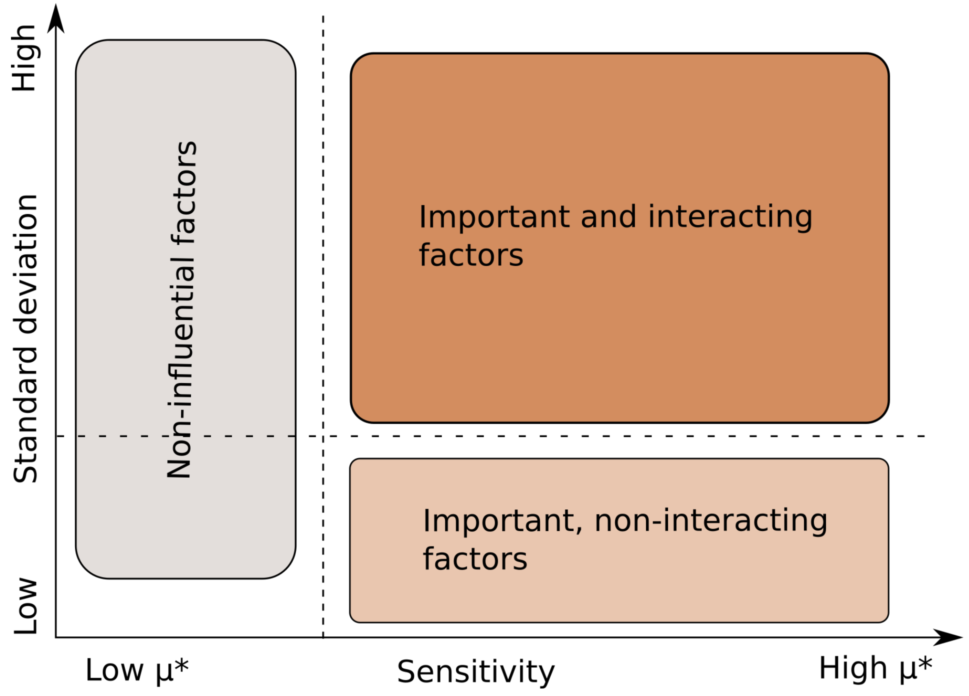
Top boundary condition	
Atmospheric forcing	Database
Precipitation	Local observations + SAFRAN (δZ = 8km)
Surface air pressure	SAFRAN data
Temperature of air	Local observations + SAFRAN
Shortwave & longwave radiation	SAFRAN
Windspeed	SAFRAN



Experimental setup & methodology

Morris test (Campologno et al.,2007; Morris, 1991):

- One at a time (OAT) type test
- Each parameter set is incrementally sampled from parameter space
- (Number of parameters+1)*Repetition = Number of simulations
- Absolute elementary effects(μ*) and standard deviation (σ) are quantified
- μ* vs σ plot indicates the most influential parameters & parameters that impact non-linear processes in the model
- I selected a 35% threshold to determine important parameters
- Limitations: It does not take physical constraints into account



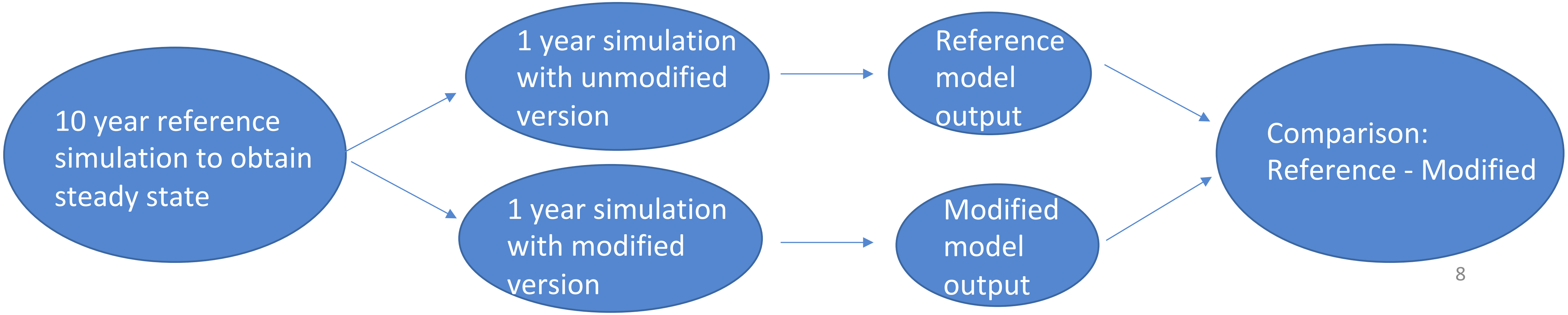
Changes in source code & Validation

Changes in the code:

- VWC_FC (Field capacity), VWC_WP (Permanent wilting point) using Van Genuchten-Mualem relationship are explicitly described in the code.
- For VWC_FC, -1m for Sand (following Richards and Weaver, 1944), -3.3m for other soil classes are used.
- For VWC_WP, -150m matric potential is used.
- QZ content depends on soil texture for thermal module. 12 cases using K_s^{ref} as a proxy are defined.

Validation:

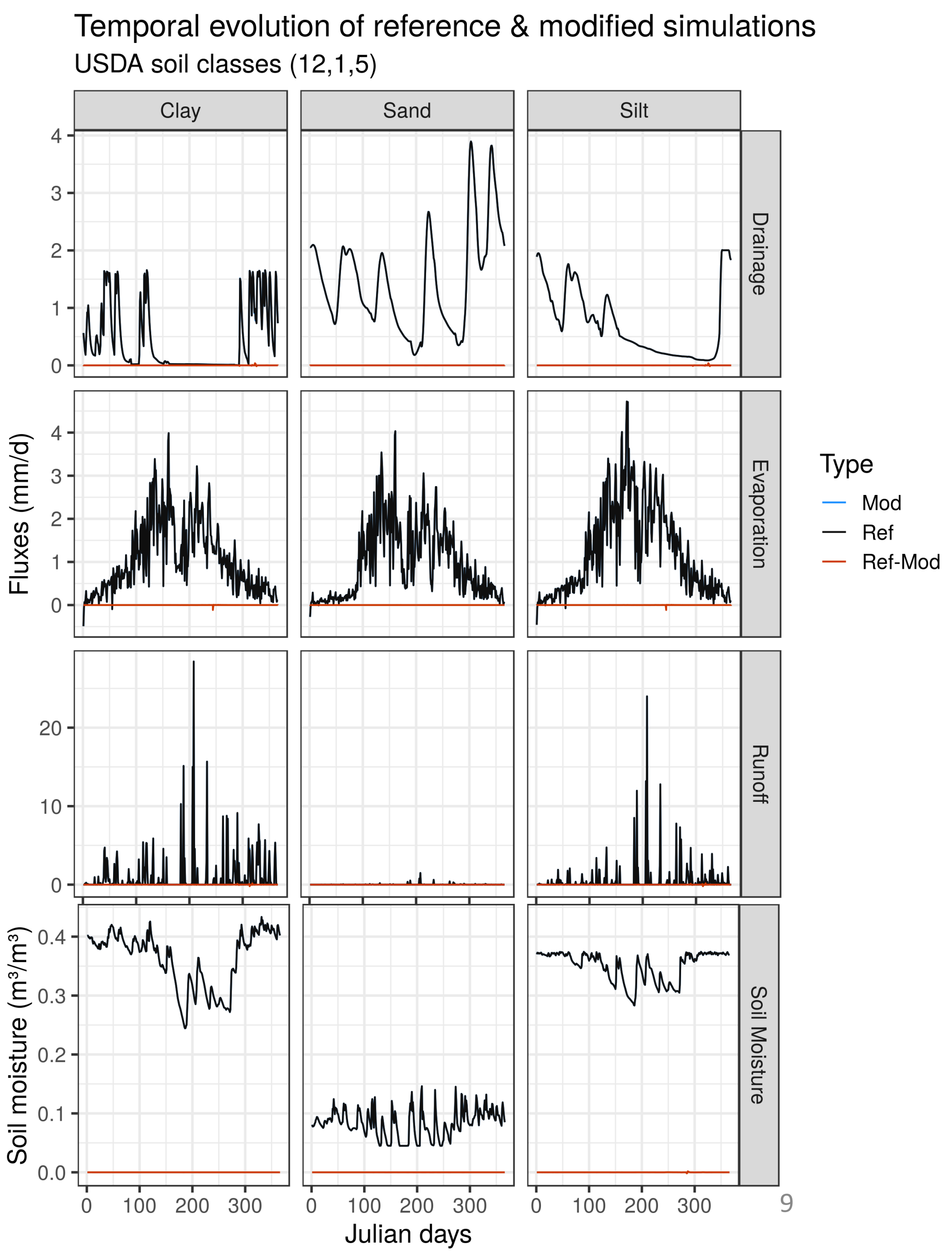
- An ORCHIDEE mesh is generated, using forcing from Avenelles basin. Free boundary condition is defined at the bottom.
- 12 soil textures classes are defined in the mesh, parameter values are taken from Carsel & Parrish (1988)



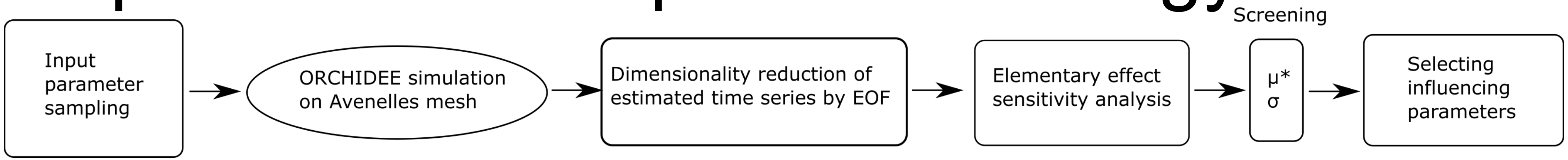
Validation

Initialization of ORCHIDEE					
Field capacity			Permanent wilting point		
Reference	Modified	Ref-Mod	Reference	Modified	Ref-Mod
0.049307	4.93E-02	9.02E-17	0.045000952	4.50E-02	0.00E+00
0.071041	7.10E-02	0.00E+00	0.057023057	5.70E-02	8.33E-17
0.121823	0.1218233	3.61E-16	0.065664191	6.57E-02	0.00E+00
0.240242	0.2402423	4.44E-16	0.103943536	0.103944	4.72E-16
0.258186	0.2581858	6.11E-16	0.090061812	9.01E-02	0.00E+00
0.165377	0.1653771	4.44E-16	0.088384692	8.84E-02	0.00E+00
0.169466	0.1694661	5.83E-16	0.11116501	0.111165	0.00E+00
0.338268	0.3382684	0.00E+00	0.196666988	0.196667	4.72E-16
0.269693	0.2696927	7.22E-16	0.149606727	0.149607	2.22E-16
0.267245	0.2672452	0.00E+00	0.170370881	0.170371	9.44E-16
0.336954	0.3369539	8.33E-16	0.266480639	0.266481	0.00E+00
0.34695	0.3469497	0.00E+00	0.270691057	0.270691	6.66E-16

- At initialization, calculated and reference VWC_FC, VWC_WP are the same
- The resulting fluxes for different USDA classes are identical



Experimental setup & methodology



Simulation characteristics and analysis

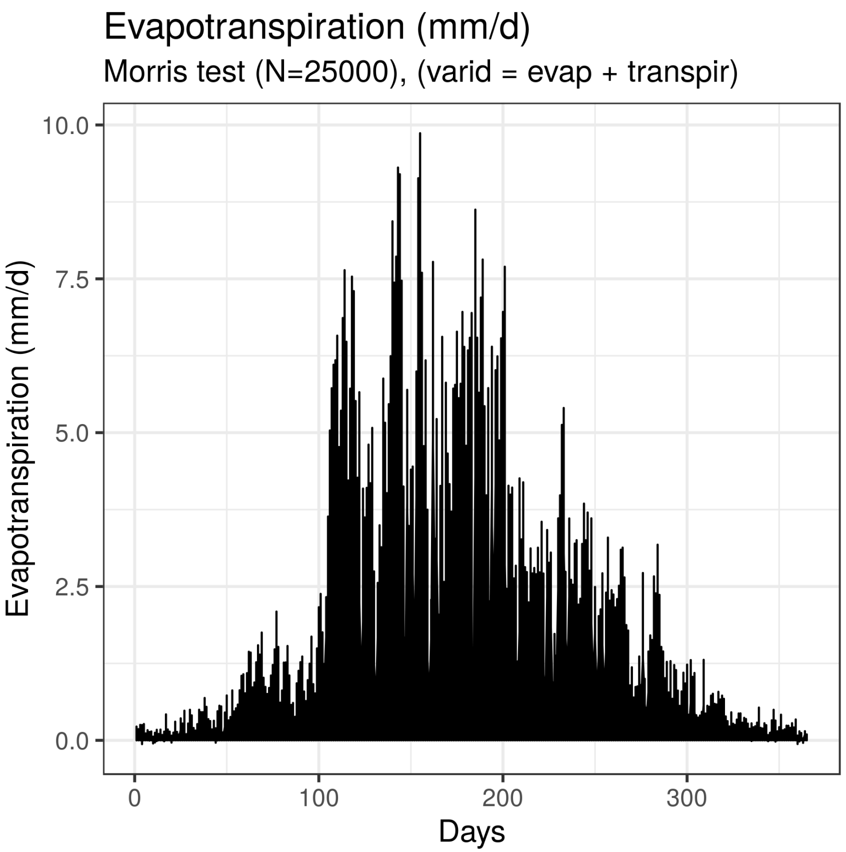
- **24 parameters** are selected for analysis, their impact on water and energy fluxes are analyzed
- Steady state is obtained by a **10 year spin-up** period for each simulation prior to test for water and energy fluxes
- **1000 repetitions** with **24 levels** of increment over parameter space are selected (A total of 25000 simulations per year).
- We reduced dimensionality of resulting time series with EOF functions to limit information loss for Morris test
- **Actual evapotranspiration, runoff, recharge** are analyzed.

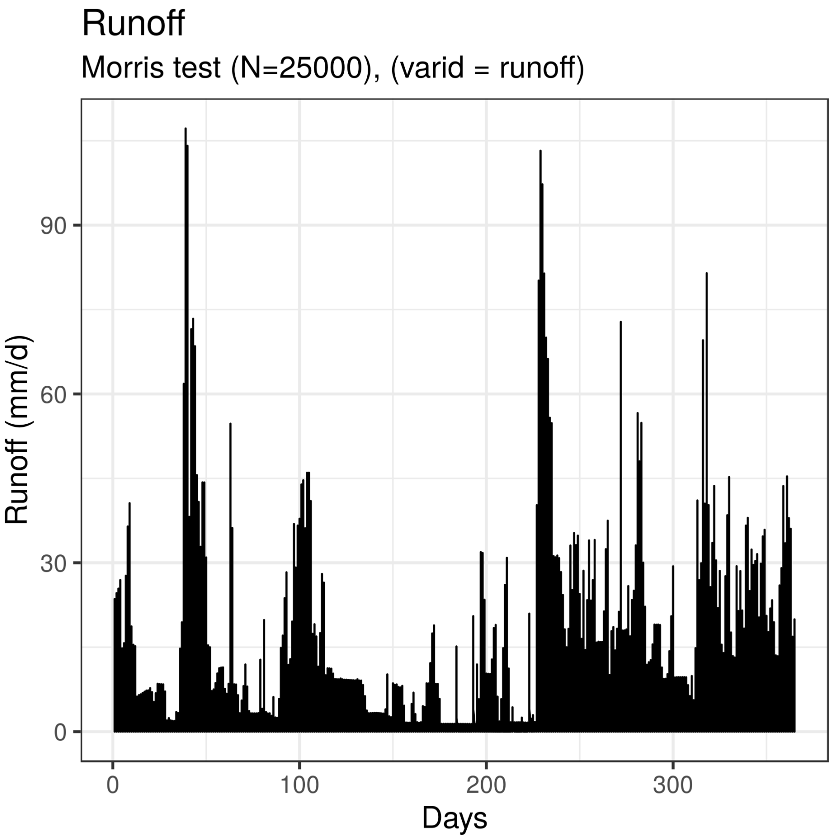
Parameter space

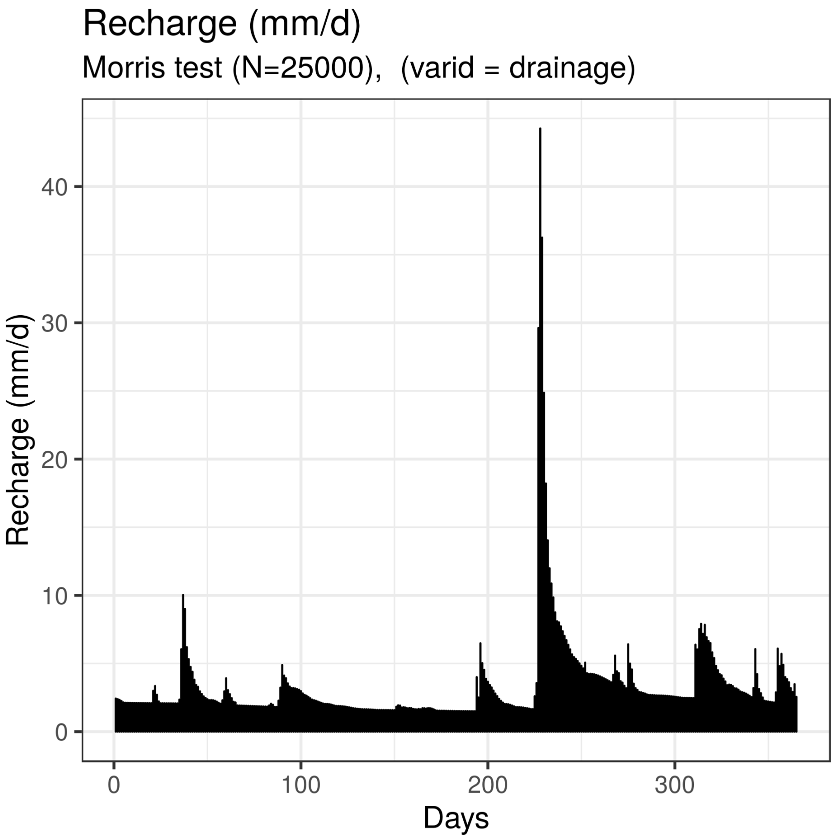
Name of the parameter	Name of the parameter	Unit	Minimum	Maximum
$Z0_{bare}$	Bare soil roughness length	m	0.001	0.1
$Emis_{scal}$	Surface emissivity coefficient	-	0.7	1
C_{drag}	Drag coefficient of the foliage	-	0.1	0.4
Ct	Heat transfer coefficient of the leaf	-	0.05	0.1
qs_{int}^{cst}	Transformation coefficient from leaf area index into interception reservoir	-	0.01	0.05
ALB_{LEAF}^{NIR}	Leaf albedo of vegetation type, near infrared albedo	-	0.2	0.33
ALB_{LEAF}^{VIS}	Leaf albedo of vegetation type, visible albedo	-	0.04	0.12
$Z0_{OVERHEIGHT}$	Coefficient for z0 from height	-	0,02	0,1
A1	Factor for describing the effect of leaf to air vapor difference on stomatal conductance	-	0,8	0,9
B1	Factor for describing the effect of leaf to air vapor difference on stomatal conductance	-	0,05	0,2
VC_{MAX}^{25}	Maximum rate of Rubisco activity-limited carboxylation at 25°C	$\mu mol/m^2$	20	70
LAI_{MAX}	Maximum value of Leaf area index	m^2/m^2	1.5	3.5
R_{STRUCT}	Structural resistance	frac	2	3
$HYDROL_{HUM}^{CSTE}$	Root profile	m	1	7
THROUGHFALL%	Percent of precipitation that is not intercepted by the canopy	frac	0	0.5
R_{VEG}^{PFT}	Artifical parameter to modify canopy resistance	frac	0.5	1
K_s^{ref}	Saturated hydraulic conductivity	mm/d	4.8	7128
α^{ref}	Van genuchten coefficient α	1/mm	0.0005	0.0145
n^{ref}	Van genuchten coefficient n	-	1.09	2.68
θ_{SAT}	Porosity	-	0.15	0.46
θ_{RES}	Residual soil water content	mm	0.01	0.1
$KFACT_{DECAY}$	Factor for Ks decay with depth	-	1	3
$DEPTH_H$	Depth of hydrological soil column	m	2	10
P_{CENT}	Percentage for transpiration sink	frac	0.5	1

Source: ORCHIDAS website

Results - Simulations





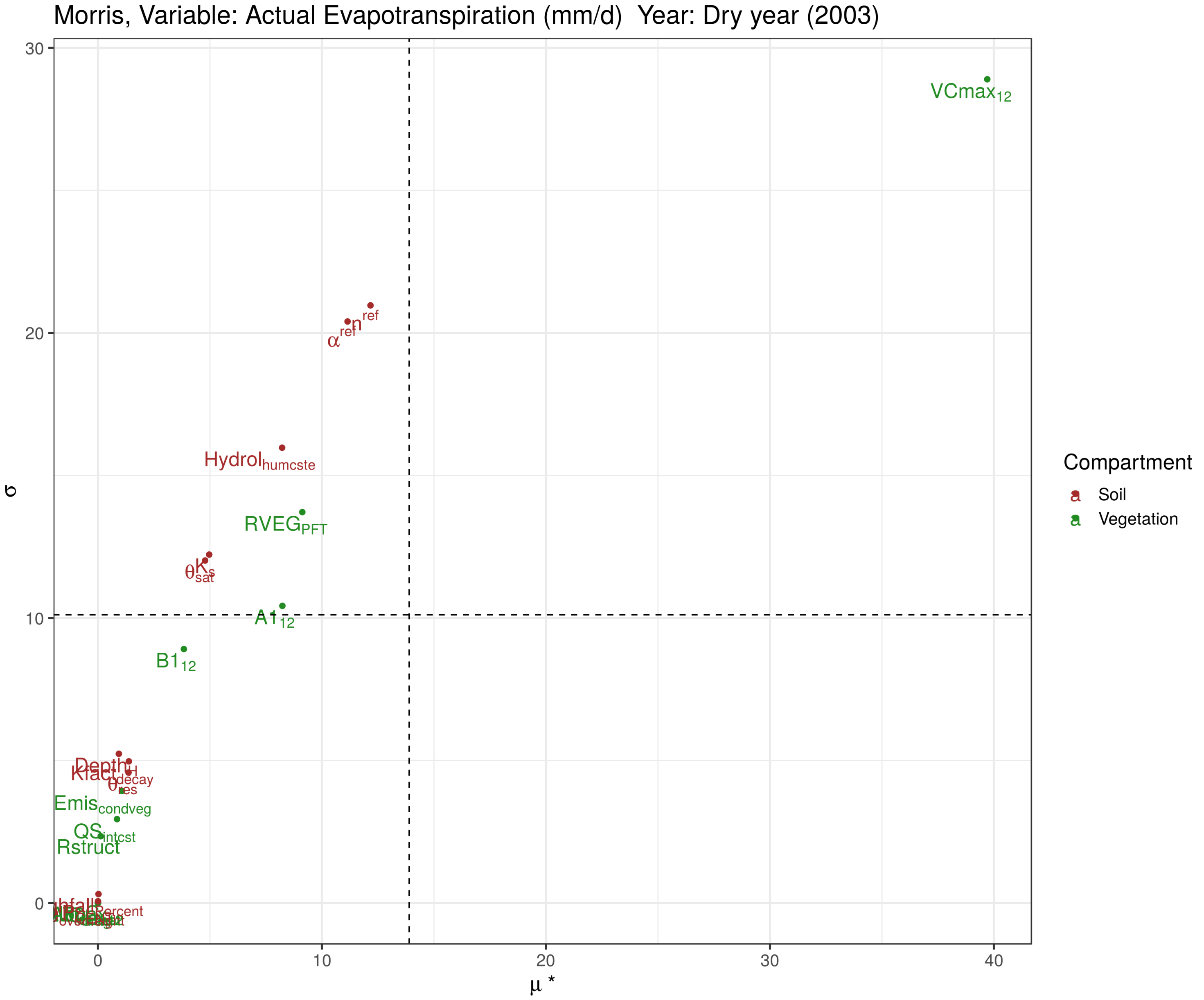


- First 3 principal component explains 99% of the variance proportion

Results – Actual evapotranspiration

- $VC25_{max}$ is the most important parameter.

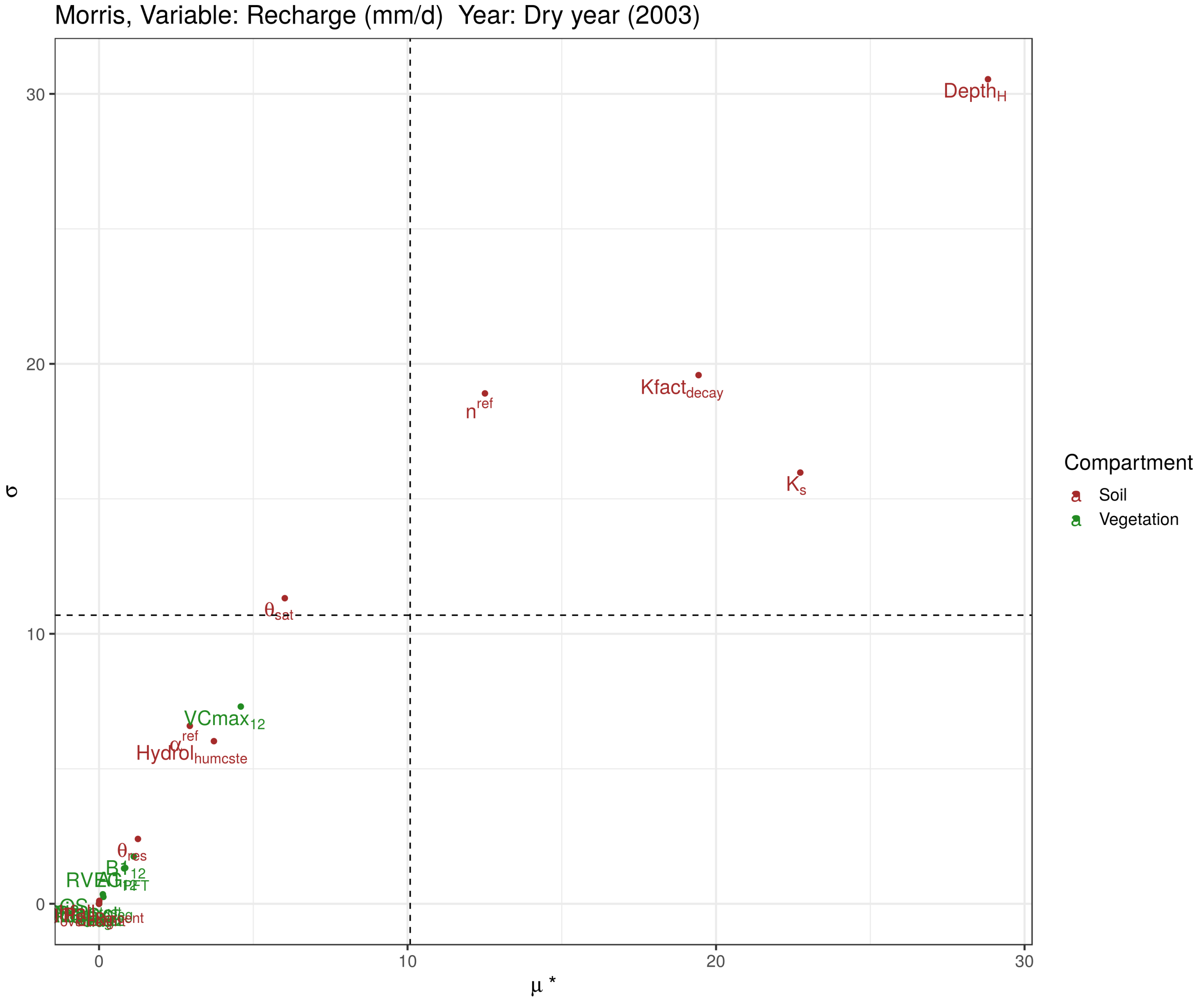
- Van Genuchten parameters along with saturated hydraulic capacity of soil, root profile, structural resistance of vegetation are relatively important parameters for evapotranspiration.



Results - Recharge

- Soil layer thickness, hydraulic conductivity, n, θ_{sat}, decay rate of hydraulic conductivity at top layer are relatively more important than other parameters

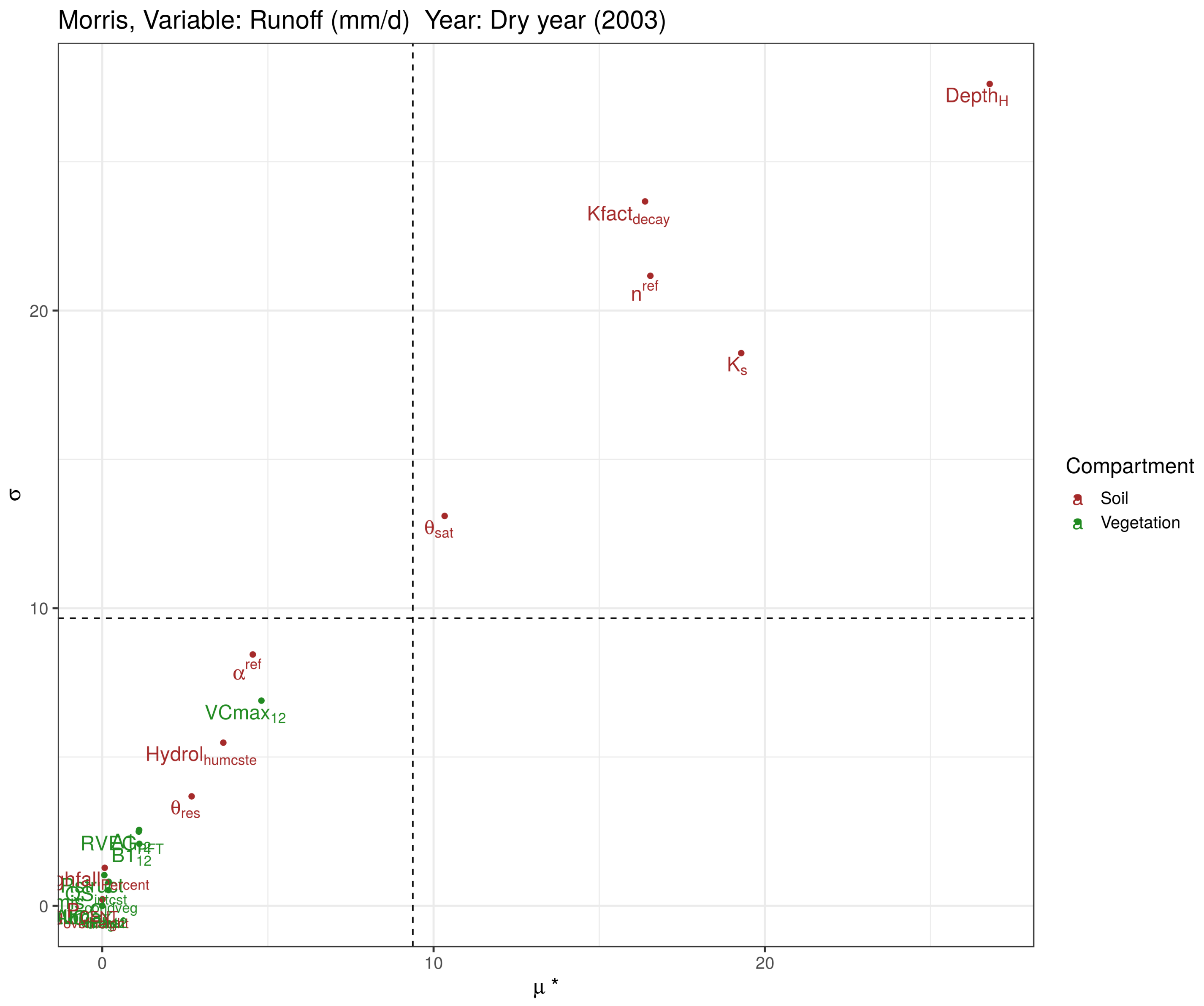
- There is no significant influence of different hydrological states on relative parameter importance



Results - Runoff

- Soil layer thickness, hydraulic conductivity, Van Genuchten parameters α, n, θ_{sat}, decay rate of hydraulic conductivity at top layer are relatively more important than other parameters

- There is no significant influence of different hydrological states on relative parameter importance



Conclusion & Perspectives

- A sensitivity analysis framework is developed to quantify important parameters of ORCHIDEE
- 24 parameters characterizing vegetation, surface, soil column are tested
- Soil column thickness, $VC25_{max}$, $Kfact_{decay}$, K_s^{ref}, α, θ_{sat}, n are found to be most important parameters impacting evapotranspiration, recharge, and runoff
- A calibration methodology based on this results will be developed

Thank
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