

# Soil hydrology

**Agnès Ducharne**  
UMR METIS, UPMC  
[agnes.ducharne@upmc.fr](mailto:agnes.ducharne@upmc.fr)

# Outline

## 1. Introduction

- Water budget and soil hydrology

## 2. The multi-layer « CWRR » scheme

- Processes, parameters, options

## 3. Forcing conditions

- Vegetation/LC, soil texture, slope

**More details on the Wiki**

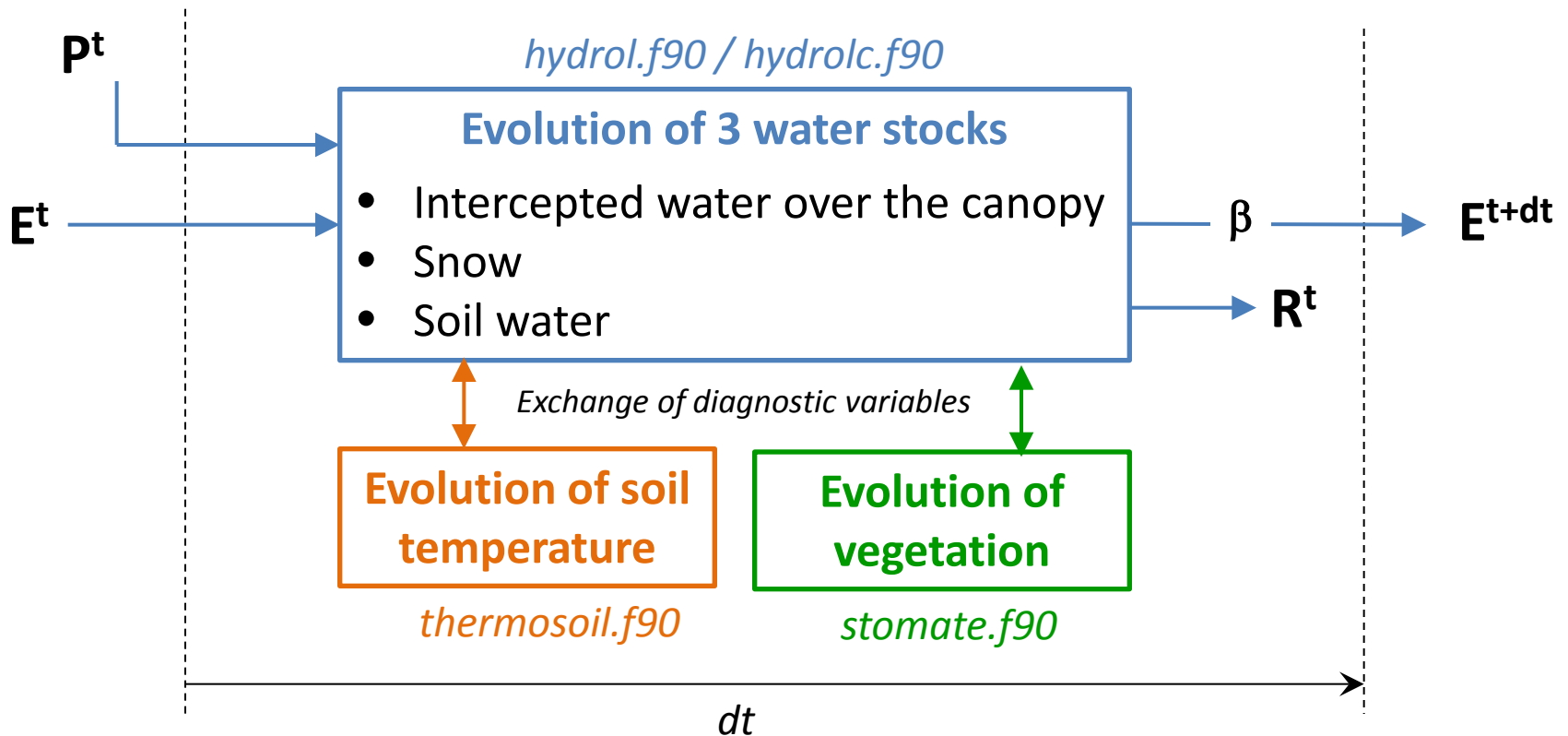
[http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/eqs\\_hydrol.pdf](http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/eqs_hydrol.pdf)

Reference papers: de Rosnay et al., 2000; de Rosnay et al., 2002; d'Orgeval et al., 2008;  
Campoy et al., 2013

PhD theses : de Rosnay, 1999; d'Orgeval, 2006; Campoy, 2013

# Water budget and soil hydrology

$$dS/dt = P - E - R$$

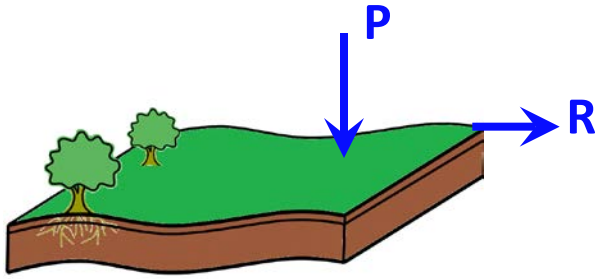


**We will focus on soil water and the related water fluxes (soil hydrology)  
No interception, no snow, no soil water freezing today**

# Two versions of soil hydrology

## Two-layer = Choisnel = ORC2

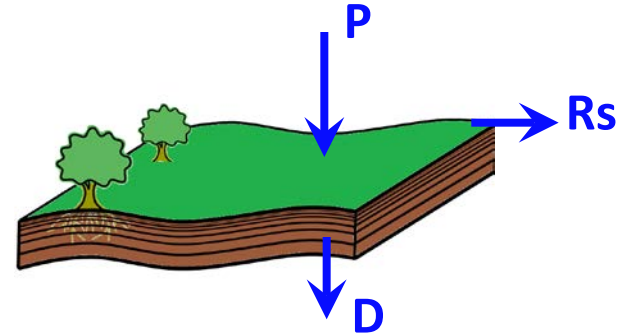
Ducoudré et al., 1993; Ducharne et al., 1998; de Rosnay et al. 1998



- Conceptual description of soil moisture storage
  - 2-m soil and 2-layers
  - Top layer can vanish
  - Constant available capacity (between 0 and 100%)
  - Runoff when saturation is reached
  - No drainage from bottom
- We just diagnose the amount of runoff for the routing scheme

## Multi-layer = CWRR = ORC11

de Rosnay et al., 2002; d'Orgeval et al., 2008; Campoy et al., 2013



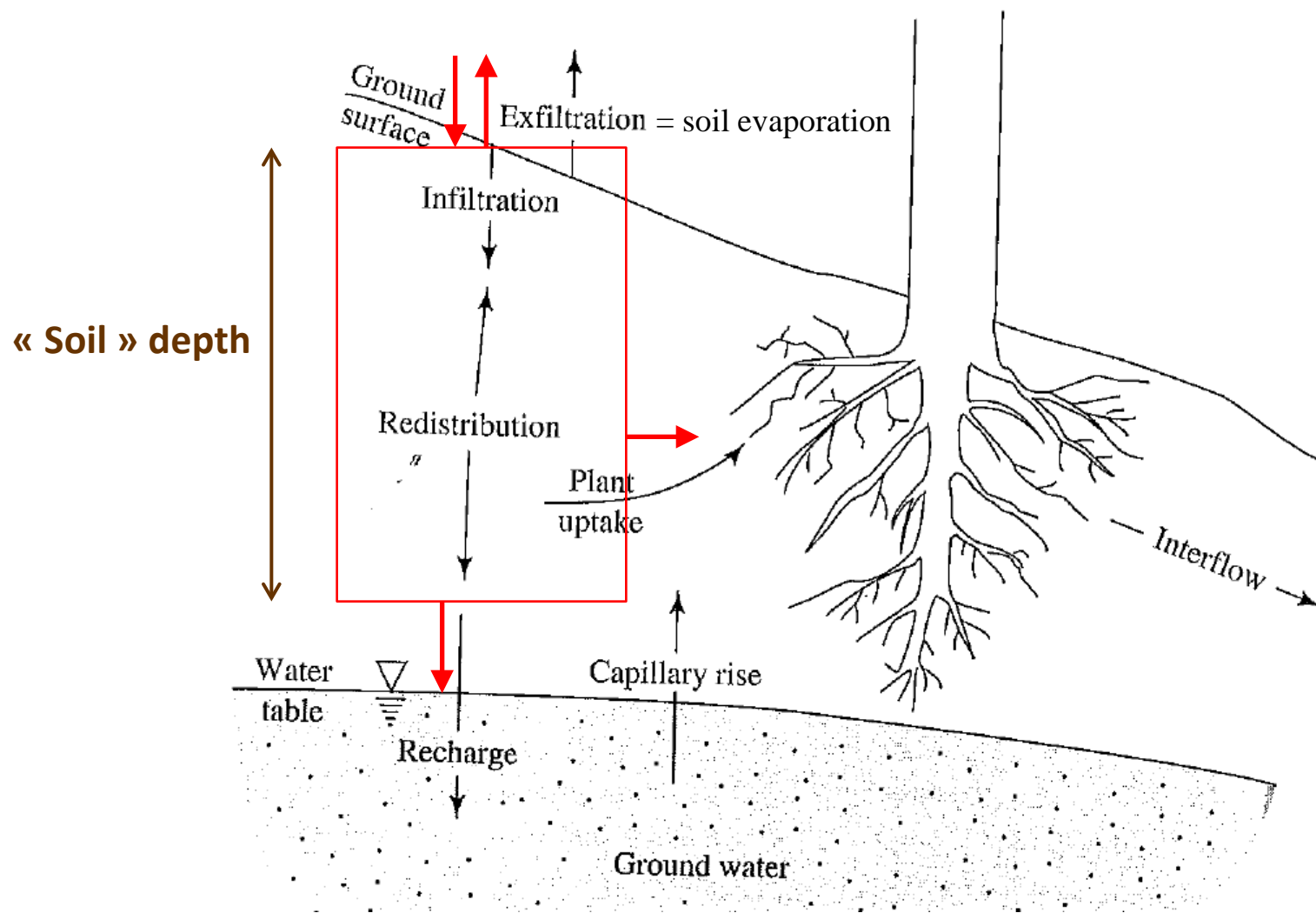
- Physically-based description of soil water fluxes using Richards equation
- 2-m soil and 11-layers
- Formulation of Fokker-Planck
- Infiltration based on van Genuchten formulation
- Evaporation based on texture
- Esol – Infiltration
- Drainage at the bottom

*In run.def*

**HYDROL\_CWRR = n / y**

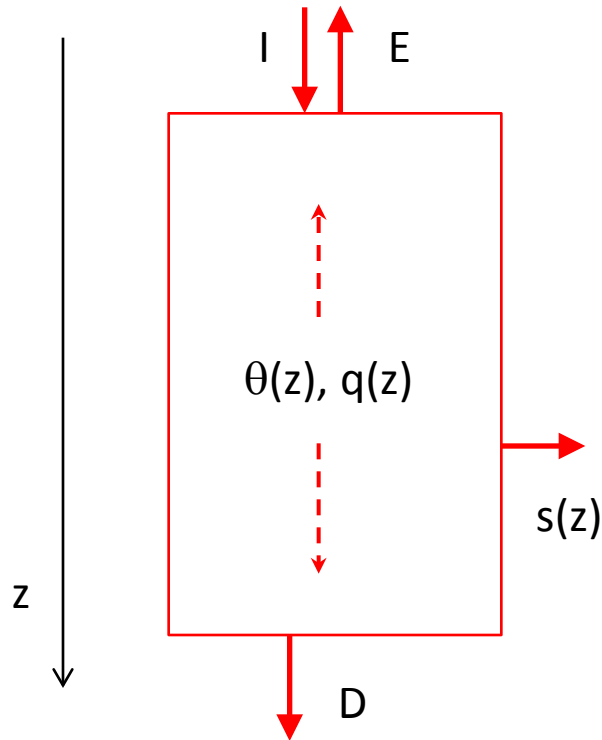
→ either hydrolc.f90 or hydrol.f90

# What is modeled ?



# How is it modeled ?

1. We assume 1D vertical water flow below a flat surface



$\theta$  : volumetric water content in  $\text{m}^3.\text{m}^{-3}$

$q$  : flux density in  $\text{m}.\text{s}^{-1}$

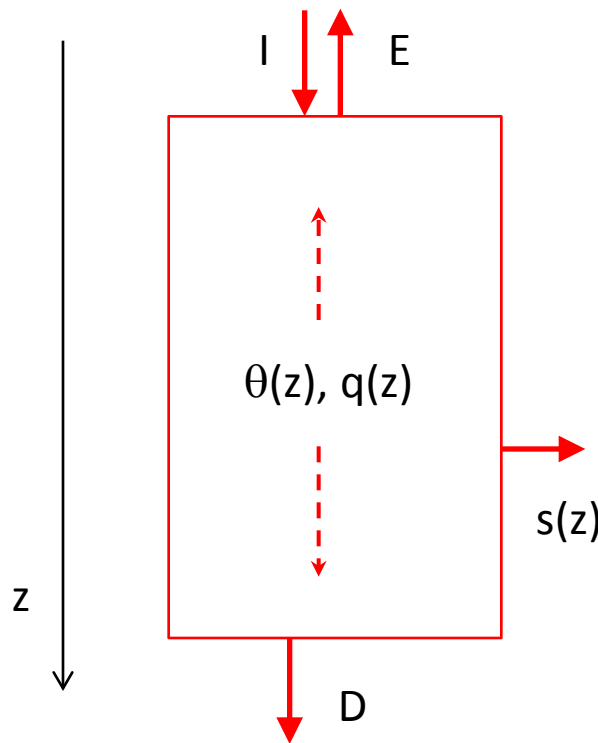
$h$  : hydraulic potential in  $\text{m}$

$K$  : hydraulic conductivity in  $\text{m}.\text{s}^{-1}$

$s$  : transpiration sink in  $\text{m}^3.\text{m}^{-3}.\text{s}^{-1}$

# How is it modeled ?

1. We assume 1D vertical water flow below a flat surface



2. Continuity :

$$\frac{\partial \theta}{\partial t} + \frac{\partial q}{\partial z} = -s$$

3. Motion = diffusion equation because of low velocities in porous medium

$$q(z) = -K(z) \frac{\partial h}{\partial z}$$

4. Hydraulic head  $h$  quantifies the gravity and pressure potentials

$$h = -z + \psi \quad \psi \text{ is the matric potential (in m, } <0)$$

Richards equation

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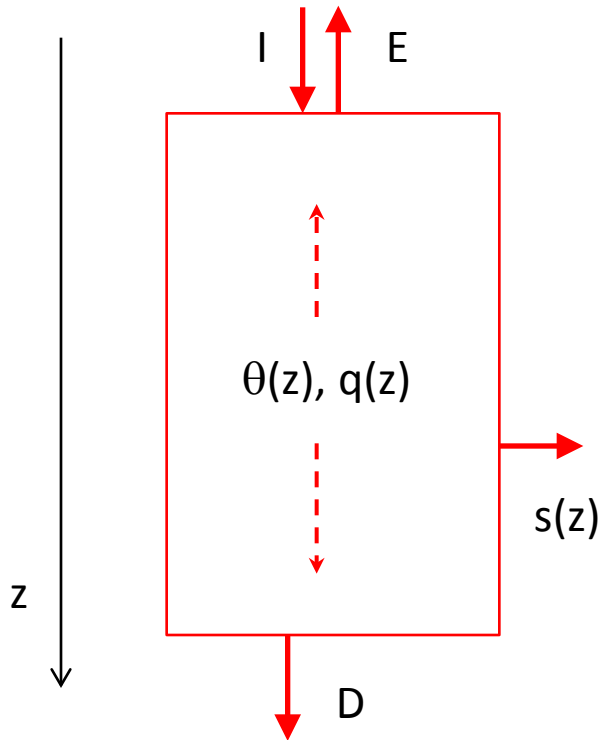
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$K$  : hydraulic conductivity in  $\text{m} \cdot \text{s}^{-1}$

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4. Hydraulic head  $h$  quantifies the gravity and pressure potentials

$$h = -z + \psi \quad \psi \text{ is the matric potential (in m, } <0)$$

5.  $K$  and  $\psi$  depend on  $\theta$  (unsaturated soils)

$$q(z) = -K(\theta) \left[ \frac{\partial \psi}{\partial z} - 1 \right]$$

$$q(z) = -D(\theta) \frac{\partial \theta}{\partial z} + K(\theta)$$

$$D(\theta) = K(\theta) \frac{\partial \psi}{\partial \theta}$$

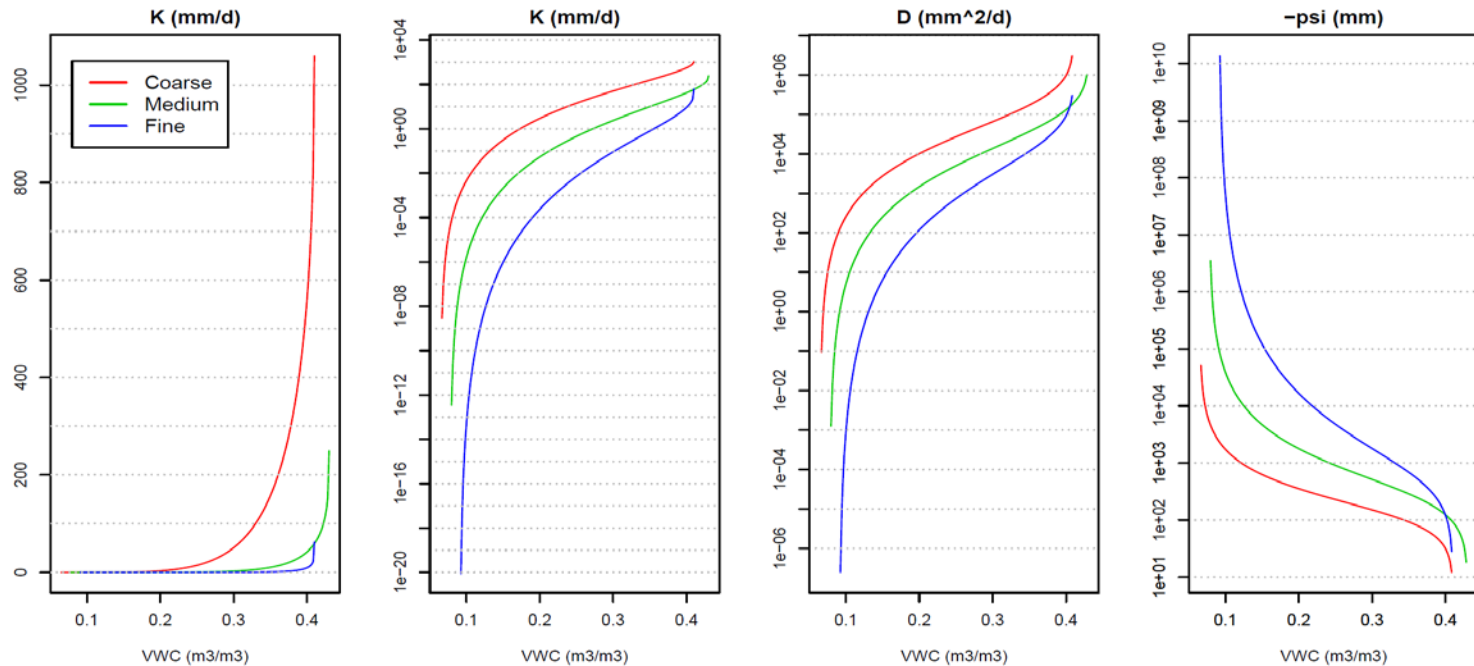
$D$  is the diffusivity (in  $\text{m}^2.\text{s}^{-1}$ )

Richards equation



# The hydrodynamic parameters

- **K and D depend on saturated properties (measured on saturated soils) and on  $\theta$**
- Their dependance on  $\theta$  is very non linear
- In ORCHIDEE, this is decribed by the so-called **Van Genuchten-Mualem relationships**:



$$K(\theta) = K_s \sqrt{\theta_f} \left( 1 - \left( 1 - \theta_f^{1/m} \right)^m \right)^2$$

$$\psi(\theta) = -\frac{1}{\alpha} \left( \theta_f^{-1/m} - 1 \right)^{1/n}$$

$$D(\theta) = \frac{(1-m)K(\theta)}{\alpha m} \frac{1}{\theta - \theta_r} \theta_f^{-1/m} \cdot \left( \theta_f^{-1/m} - 1 \right)^{-m}$$

$$\theta_f = (\theta - \theta_r) / (\theta_s - \theta_r)$$

$$m = 1 - 1/n$$

**Parameters:**


$\theta_s$   $\theta_r$   $K_s$   $n$

$\alpha = -1/\psi_{ae}$


# Modifications of $K_s$ with depth

$K_s(z)$  in mm/d

(2)  $K_s$  decreases exponentially with depth below 30 cm




(1)  $K_s^{\text{ref}} = 1060$  mm/d  
[Sandy Loam/Zobler class 1]



(3)  $K_s$  also increases towards the surface because of bioturbation

Orange: grass PFT,  
 $c_j = \text{humcste} = 4$

Yellow: forest PFT,  
 $c_j = \text{humcste} = 0.8$



# Modifications of $K_s$ with depth

## (a) $K_s$ decreases exponentially with depth

- This follows observational reports (starting from Beven & Kirkby, 1979)
- In ORCHIDEE, the exponential decay starts at 30 cm

$$F_K(z) = \min(\max(\exp(-f(z - z_{\text{lim}})), 1/F_K^{\text{max}}), 1)$$

Parameters:  $K_s^{\text{ref}}$   $f$   $z_{\text{lim}}$   $F_K^{\text{max}}$

## (b) $K_s$ also increases towards the surface because of bioturbation (roots)

$$F_{K_{\text{root}}}(z, c) = \prod_{j \in c} \max \left( 1, \left( \frac{K_s^{\text{max}}}{K_s^{\text{ref}}} \right)^{f^j (1 - c_j z) / 4} \right)$$

Parameters:  $K_s^{\text{ref}}$   $K_s^{\text{max}}$   $c_j$  (= humcste)  $f^j$  (= veget\_max)

## (c) Combined effect

$$K_s^*(z, c) = K_s^{\text{ref}} F_K(z) F_{K_{\text{root}}}(z, c)$$

$K_s^{\text{ref}}$  depends on soil texture

# Modifications of Ks with depth

## (a) Ks decreases exponentially with depth

- This follows observational reports (starting from Beven & Kirkby, 1979)
- In ORCHIDEE, the exponential decay starts at 30 cm

$$F_K(z) = \min(\max(\exp(-f(z - z_0)), 0), 1)$$

Parameters:  $f$

## (b) Ks also increases with vegetation

## Disturbance (roots)

All this is done in `hydrol_var_init`  
 Details can be found in :

[http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/egs\\_hydrol.pdf](http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/egs_hydrol.pdf)

$$F_{Kroot}(z, c) = \max\left(1, \left(\frac{K_s^{max}}{K_s^{ref}}\right)^{f^j(1-c_jz)/4}\right)$$

Parameters:  $K_s^{ref}$   $K_s^{max}$   $c_j^z$  (+  $f^j = veget\_max$ )

## (c) Combined effect

$$K_s^*(z, c) = K_s^{ref} F_K(z) F_{Kroot}(z, c)$$

$K_s^{ref}$  depends on soil texture

# Finite difference integration

- The differential equations of continuity and motion are solved using finite differences :

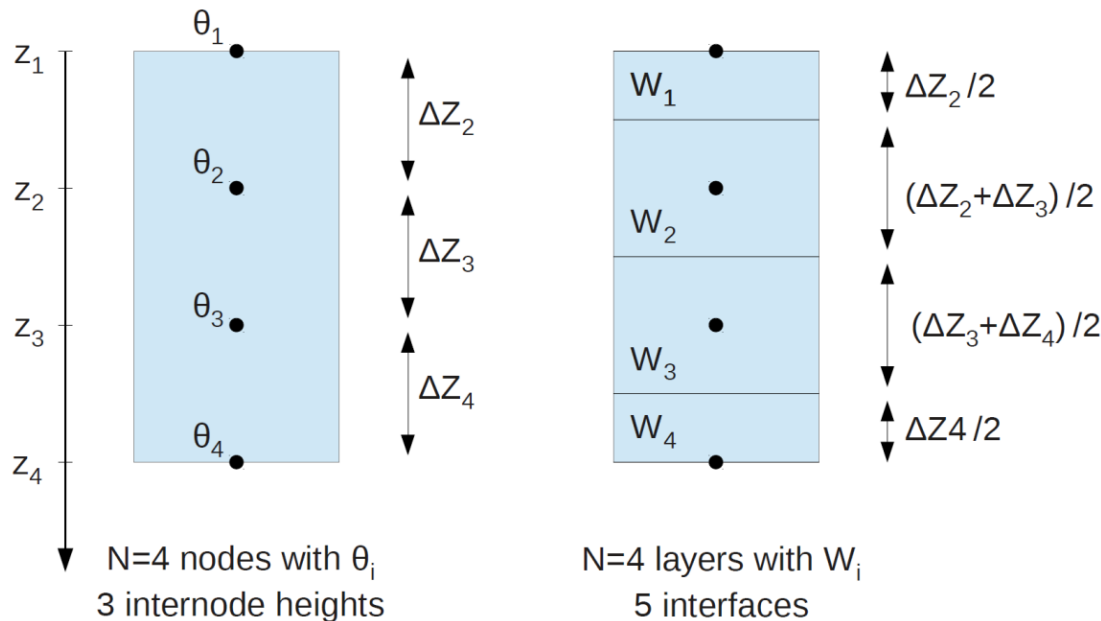
$$\frac{W_i(t + dt) - W_i(t)}{dt} = Q_{i-1}(t + dt) - Q_i(t + dt) - S_i$$

$S_i$  = transpiration sink

$$\frac{Q_i}{A} = -\frac{D(\theta_{i-1}) + D(\theta_i)}{2} \frac{\theta_i - \theta_{i-1}}{\Delta Z_i} + \frac{K(\theta_{i-1}) + K(\theta_i)}{2}$$

$A$ : grid-cell area

- The soil column is discretized using  $N$  **nodes**, where we calculate  $\theta_i$
- Each node is contained in one **layer**, with a total water content  $W_i$
- The fluxes  $Q_i$  are calculated at the **interface** between two layers



$W_i$  is obtained by vertical integration of  $\theta(z)$  in layer  $i$ , assuming a linear variation of  $\theta(z)$  between 2 nodes

$$W_i = [\Delta Z_i (3\theta_i + \theta_{i-1}) + \Delta Z_{i+1} (3\theta_i + \theta_{i+1})]/8$$

$$W_1 = [\Delta Z_2 (3\theta_1 + \theta_2)]/8$$

$$W_N = [\Delta Z_N (3\theta_N + \theta_{N-1})]/8$$

## To sum up water diffusion

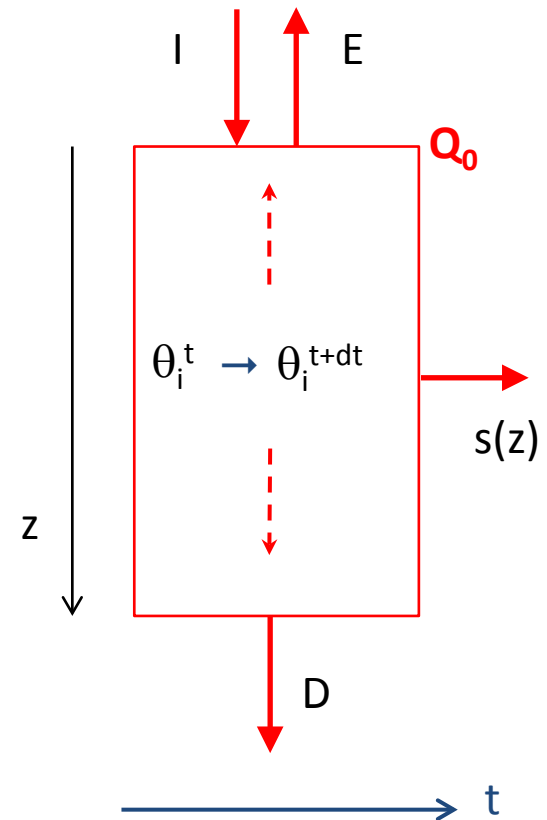
- **The prognostic variables are  $\theta_i$  at the nodes**
- They are updated **simultaneously** by solving a tridiagonal matrix
- **Their evolution is driven by**
  - the soil properties  $K(z)$  and  $D(z)$
  - the vertical discretization (soil depth and node position  $Z_i$ )
  - the transpiration sink  $s_i$
  - the top and bottom boundary conditions:

$$Q_0 = I - E_g \text{ and } Q_N = D$$

**I**: infiltration

**E<sub>g</sub>** : soil evaporation

**D**: drainage



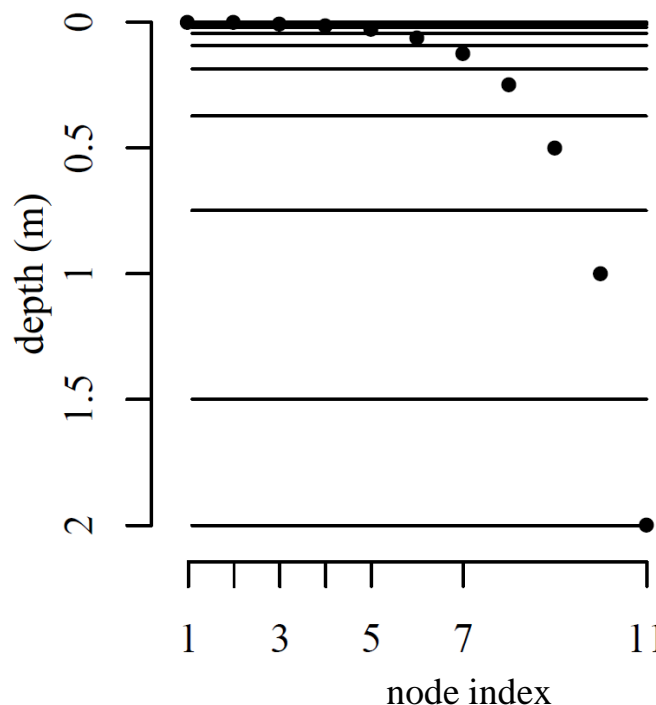
## Vertical discretization

- The vertical discretization must permit an accurate calculation of  $\theta_i$  and the related water fluxes  $Q_i$
- We need thin layers where  $\theta$  is likely to exhibit sharp vertical gradients (to better approximate the local derivative)
- Vertical discretization and boundary conditions must be decided together !

***By default, in hydrol, we use :***

- 2-m soil
- 11 nodes (layers) with geometric increase of internode distance
- consistent with free/gravitational drainage at the bottom
- consistent with exponential decrease of root density for transpiration

*(cf. de Rosnay et al., 2000)*



i	$\approx h_i$ (mm)
1	1
2	3
3	6
4	12
5	23,5
6	47
7	94
8	188
9	375
10	751
11	500

## Vertical discretization

- The vertical discretization must permit an accurate calculation of  $\theta_i$  and the related water fluxes  $Q_i$
- We need thin layers where  $\theta$  is likely to exhibit sharp vertical gradients (to better approximate the local derivative)
- Vertical discretization and boundary conditions must be decided together !
- **Alternative discretizations can be defined by externalized parameters (but use with caution)**

<b>DEPTH_MAX_H</b>	2.0 or 4.0 depending on hydrol_cwrr	m	Maximum depth of soil moisture	Maximum depth of soil for soil moisture (CWRR).
<b>DEPTH_MAX_T</b>	10.0	m	Maximum depth of the soil thermodynamics	Maximum depth of soil for temperature.
<b>DEPTH_TOPTHICK</b>	9.77517107e-04	m	Thickness of upper most Layer	Thickness of top hydrology layer for soil moisture (CWRR).
<b>DEPTH_CSTTHICK</b>	DEPTH_MAX_H	m	Depth at which constant layer thickness start	Depth at which constant layer thickness start (smaller than $z_{maxh}/2$ )
<b>DEPTH_GEOM</b>	DEPTH_MAX_H	m	Depth at which we resume geometrical increases for temperature	Depth at which the thickness increases again for temperature.



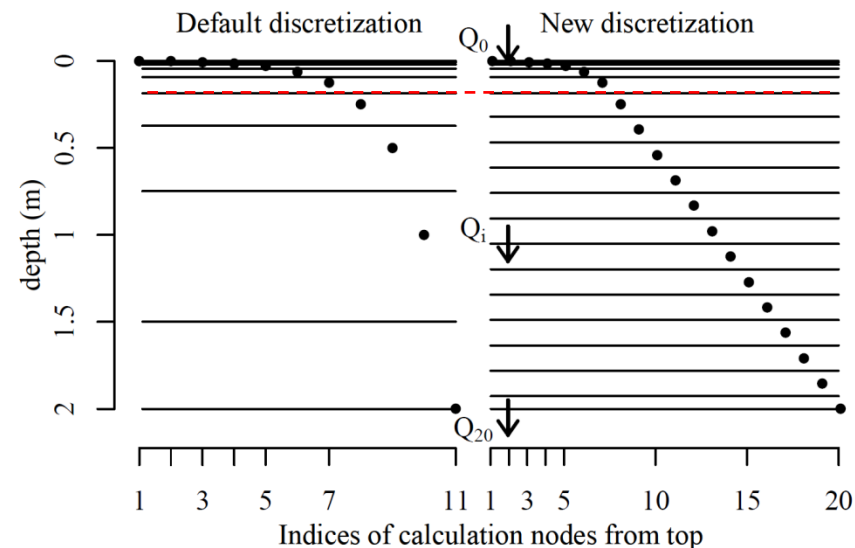
# Drainage

- **By default :**  $Q_N = K(\theta_N)$
- Based on the motion equation, this corresponds to a situation where  $\theta$  does not show any vertical variations below the modeled soil

$$q(z) = - D(\theta) \frac{\partial \theta}{\partial z} + K(\theta)$$

- The code is also numerically apt to use reduced drainage :  $Q_N = F.K(\theta_N)$  **F in [0,1]**
- With F=1, you get an impermeable bottom, like in the Choisnel scheme

- F is externalized by **free\_drain\_coef (1,1,1)**
- Reduced drainage enhances  $\theta$  gradients in the bottom soil,
- The default 11-layer discretization is not adapted anymore
- You can use the flexible discretization

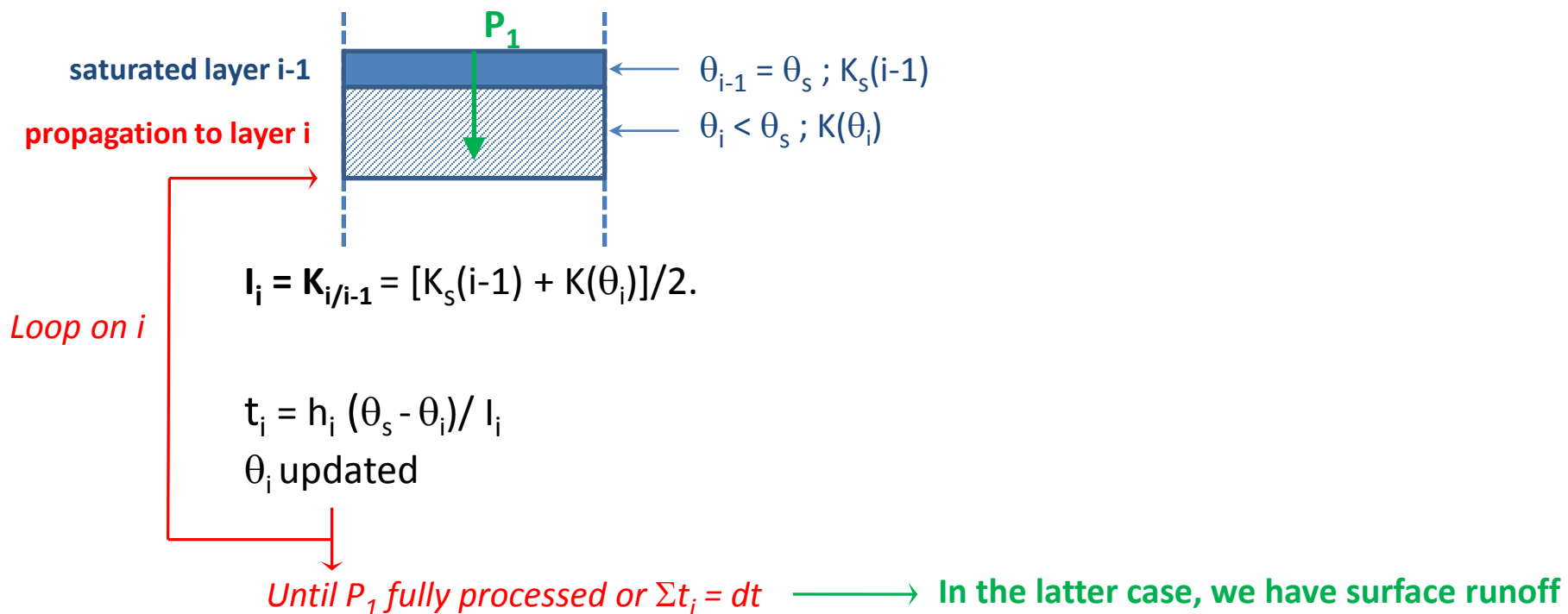


# Infiltration (and surface runoff)

- At the soil surface, throughfall can either infiltrate or run off (surface runoff)
  - The routing scheme can also produce water to infiltrate (return flow, irrigation, etc.)
  - The modeling of infiltration relies on gravitational fluxes:  $q(z) = K(\theta)$
  - With **wetting front propagation based on time splitting procedure and sub-grid-variability**
- Soil absorption is neglected
- $P_0$

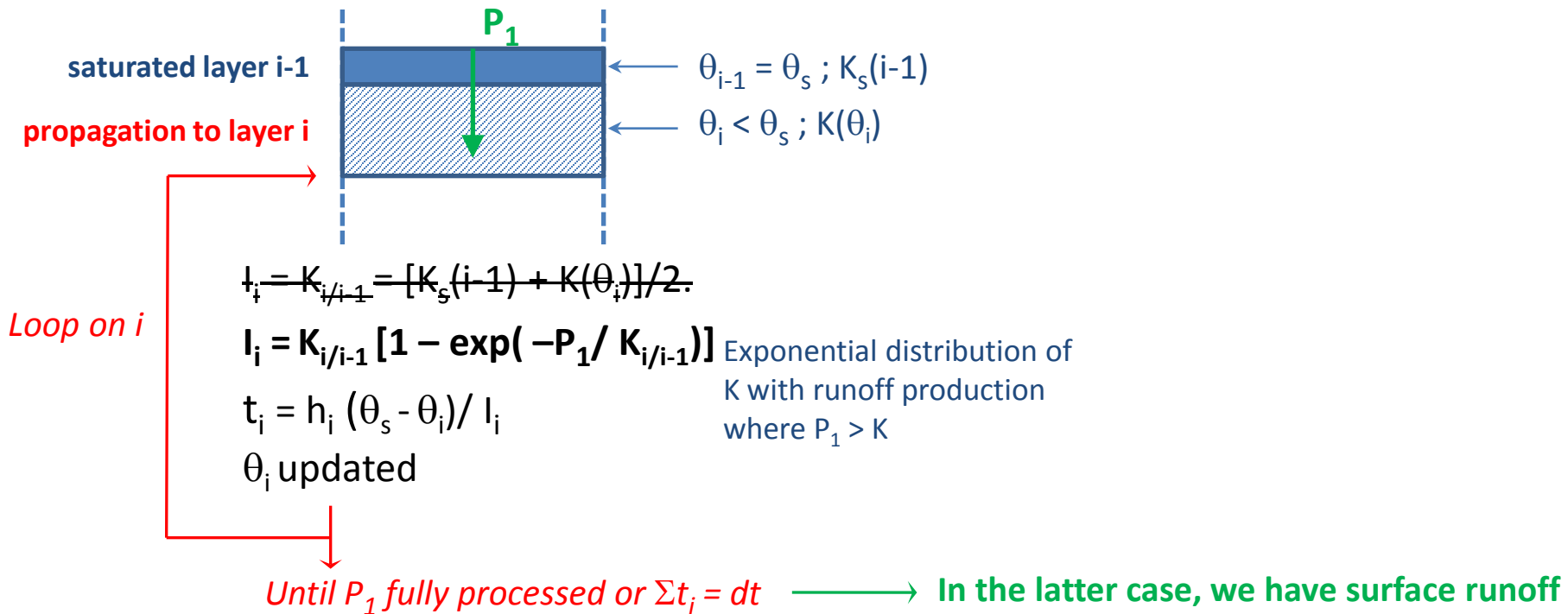
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- The modeling of infiltration relies on gravitational fluxes:  $q(z) = K(\theta)$  Soil absorption is neglected
  - With **wetting front propagation based on time splitting procedure and sub-grid-variability**
- Direct infiltration of  $P_0$  to the top soil layer (1-mm deep)
  - If  $P_0$  is sufficient, infiltration to the lowest layers of  $P_1$  (what's left of  $P_0$ ):



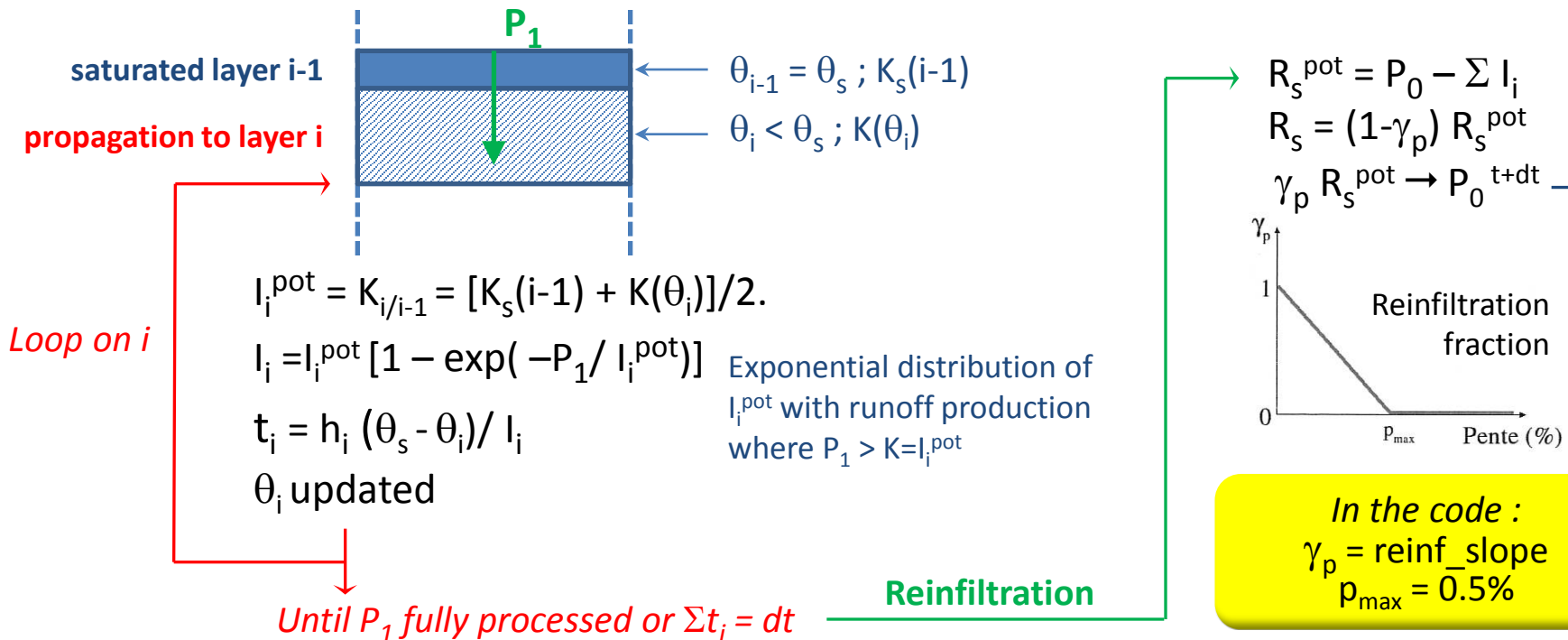
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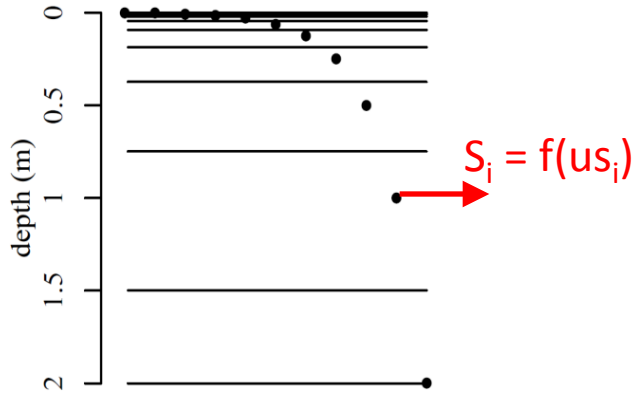


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# The transpiration sink (1)



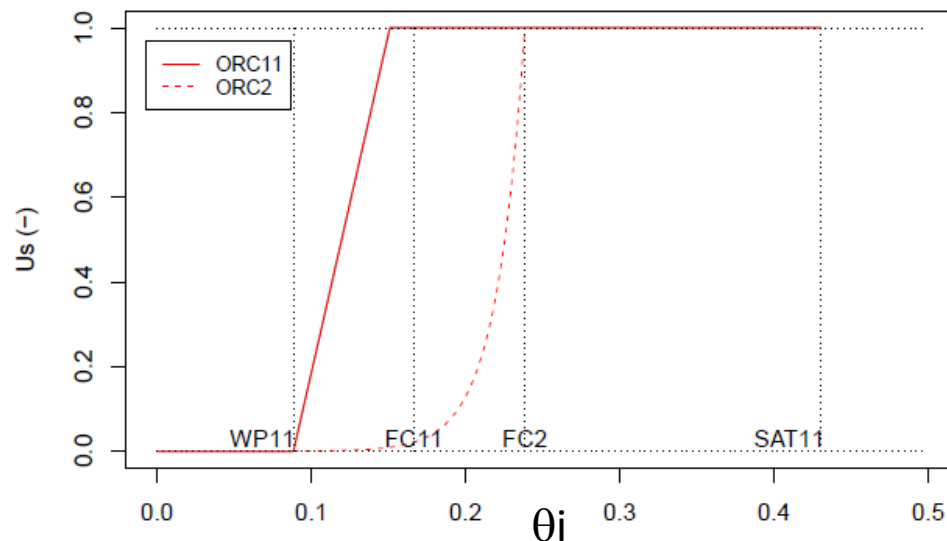
$$\frac{W_i(t + dt) - W_i(t)}{dt} = Q_{i-1}(t + dt) - Q_i(t + dt) - S_i$$

$$T_r = \sum S_i$$

$$T_r = \rho \left( 1 - \frac{I}{I_{max}} \right) U_s \frac{q_{sat}(T_s) - q_{air}}{r_a + r_c + r_{st}}$$

$$U_s = \sum us_i \quad S_i = T_r us_i / U_s$$

The dependance of  $T_r$  on  $\theta_i/W_i$  is conveyed by  $us(i)$



In the code :  
 $U_s = \text{humrel}$

## The transpiration sink (2)

The dependance of  $Tr$  on  $\theta_i/W_i$  is conveyed by  $u_s(i)$

$$u_1 = 0$$

$$u_i = n_{\text{root}}(i) \max(0, \min(1, (W_i - W_w)/(W_{\%} - W_w)))$$

$n_{\text{root}}$  : mean root density in layer  $i$

$$n_{\text{root}} = \int_{h_i} R(z) dz / \int_{\text{htot}} R(z) dz$$

$$R(z) = \exp(-c_j z)$$

$W_w$  = wilting point

$W_f$  = field capacity

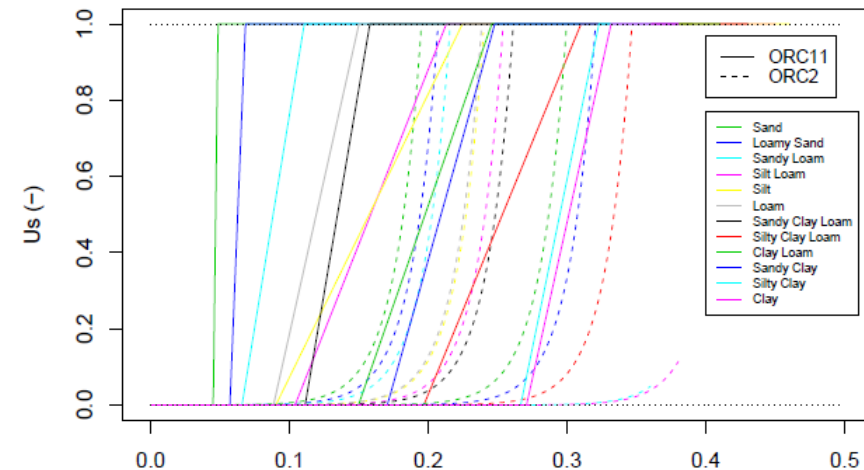
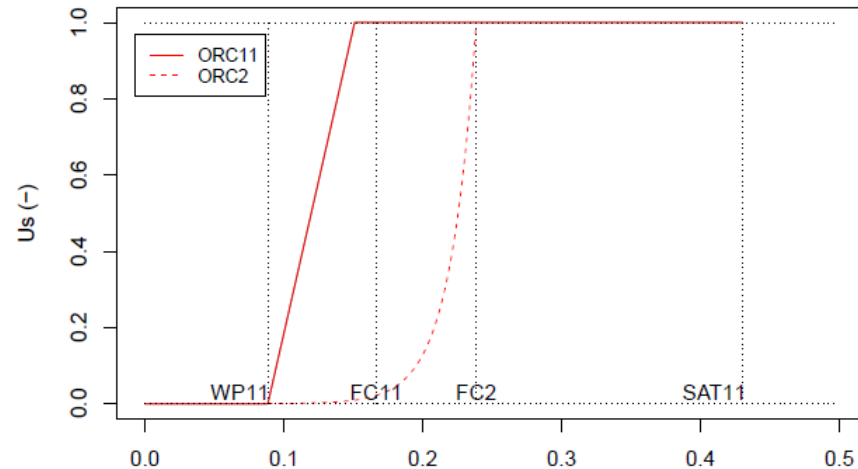
$$AWC = W_f - W_w$$

$W_{\%}$  : moisture at which  $u_s$  becomes 1 (no stress)

$$W_{\%} = W_w + p_{\%} AWC$$

In *constantes\_soil.f90*:

$$p_{\%} = \text{pcent} = (/ 0.8, 0.8, 0.8 /)$$



## Soil evaporation ( $E_g$ )

1. The soil evaporation that controls the surface boundary flux ( $Q_0 = I - E_g$ ) is known from the energy budget
2. **The issue in hydrol is to calculate the stress function  $\beta_g$  to calculate soil evaporation at the next time step**
3. **This is done by a supply/demand approach** at the end of the time step, based on the soil moisture that will prevail at the beginning of the next time step
4. **Supply/demand:  $E_g$  can proceed at potential rate unless this dries the soil out**

$$E_g = \min(E_{\text{pot}}^*, Q_{\text{up}})$$

$$E_{\text{pot}} = \frac{\rho}{r_a} (q_{\text{sat}}(T_s) - q_a) \quad > \quad E_{\text{pot}}^* = \frac{\rho}{r_a} (q_{\text{sat}}(T_w) - q_a)$$

$$\beta_g = E_g / E_{\text{pot}}$$

**In practice,  $E_g$  is calculated by 1 or 2 dummy integrations of the water diffusion, assuming no rainfall and no root sink:**

- (a) We apply  $E_{\text{pot}}^*$  as a boundary flux at the top, and test if  $\theta_1$  remains above  $\theta_r$   
If it does, then  $E_g = E_{\text{pot}}^*$
- (b) Else, we force  $\theta_1 = \theta_r$ , which drives an upward flux: the surface value  $Q_0$  gives  $Q_{\text{up}}$



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4. **Supply/demand:  $E_g$  can proceed at potential rate unless this dries the soil out**
5. **Since r3975, we can reduce the demand using a soil resistance (Sellers et al., 1992)**

***In run.def :***  
 DO\_ROIL = y  
 (default = n)

$$r_{\text{soil}} = \exp(8.206 - 4.255L/L_s)$$

L is the soil moisture in the 4 top layers  
 L<sub>s</sub> is the equivalent at saturation

$$E_g = \min\left(\frac{q_{\text{sat}}(T_w) - q_a}{r_a + r_{\text{soil}}}, Q_{\text{up}}\right)$$

**The minimum is still found via 1 or 2 dummy integrations of the water diffusion, assuming no rainfall and no root sink.**

## New features

### New diagnostics:

- **TWBR = Total water budget residu** (in kg/m<sup>2</sup>/s) to check water conservation

$$\text{TWBR} = dS/dt - (P - E - R)$$

*S includes intercepted water and snow*

Typical values are < 10<sup>-5</sup> mm/d or less

- **wtd = water table depth** (m), defined in each soiltile as the depth of deepest saturated node overlaid by an unsaturated node.

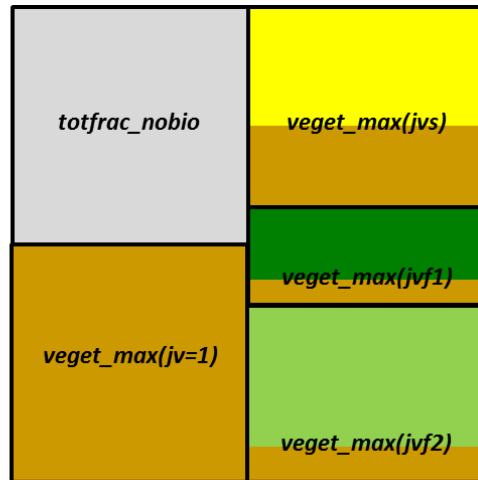
Sought from the soil bottom: if a part of the soil is saturated but underlaid with unsaturated nodes, it is not considered as a water table.

If the bottom node is not saturated, the water table depth is set to undef.

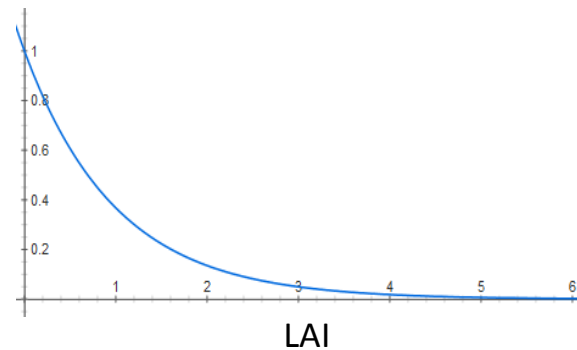
# Interactions with the vegetation/LC

**1. Horizontally**, PFTs define soil tiles with independent water budget  
(below ground tiling)

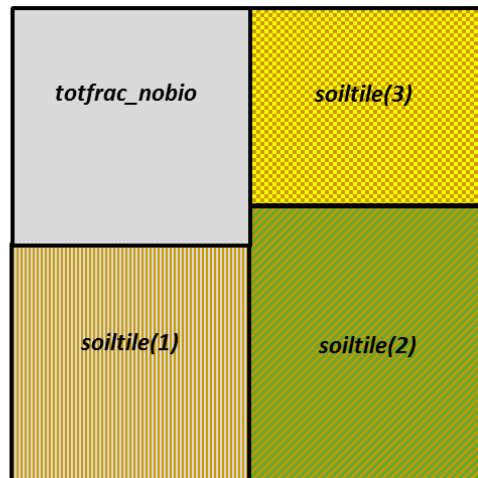
« Nobio »  
and PFTs



**Each PFT with**  
**Effective vegetation fraction**  
 $veget = veget\_max (1 - \exp(-LAI))$   
**Bare soil fraction**  
 $frac\_bare = veget\_max * \exp(-LAI)$



Soil  
columns

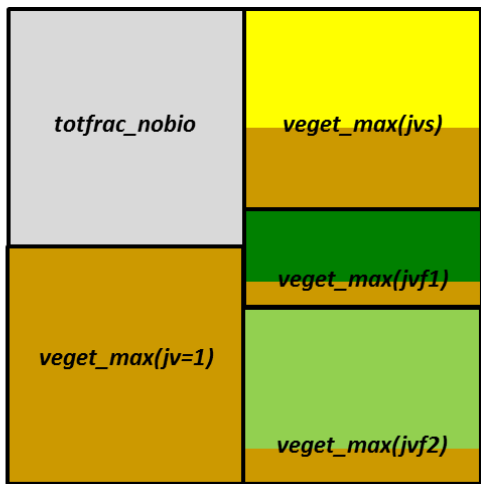


**Each soil tile with**  
 $frac\_bare\_ns$

# Interactions with the vegetation/LC

**1. Horizontally**, PFTs define soil tiles with independent water budget (below ground tiling)

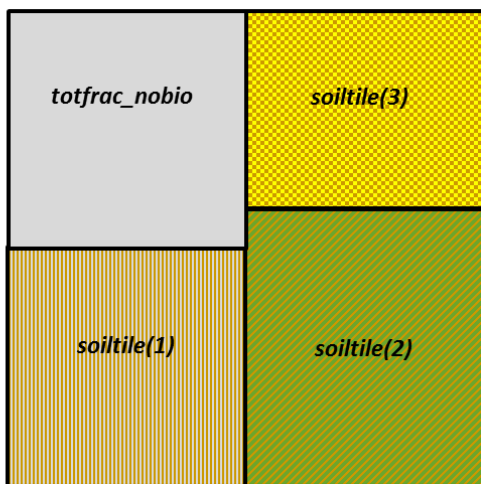
« Nobio »  
and PFTs



*Each PFT with*  
**Effective vegetation fraction**  
 $veget = veget\_max (1 - exp(- LAI))$   
**Bare soil fraction**  
 $frac\_bare = veget\_max * exp(- LAI)$

→ **In each PFT j:**  
Us and  $\beta_3$   
**Grid-cell scale:**  
 $Tr = (\sum_j veget_j \beta_3) E_{pot}$   
SUM(vbeta3)

Soil  
columns



*Each soil tile with*  
 $frac\_bare\_ns$

→ **In each soiltile c:**  
 $\beta_4$  calculation  
Independent water budget  
**Grid-cell scale:**  
 $E_{soil} = (\sum_c frac\_bare\_ns_c \beta_g) E_{pot}$   
vbeta4

# Interactions with the vegetation/LC

## 2. Vertically, ORCHIDEE defines a root density profile

In each PFT j  $R_j(z) = \exp(-c_j z)$

In each soil layer i  $n_{\text{root}}(i)$  is the mean root density  
with  $\sum_i n_{\text{root}}(i) = 1$



It controls:

**(1) the water stress on transpiration in each soil layer i**

$$u_i = n_{\text{root}}(i) \max(0, \min(1, (W_i - W_w) / (W_{\%} - W_w)))$$

**(2) the increase of Ks towards the surface ( $F_{K_{\text{root}}}$ )**

# Interactions with the vegetation/LC

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In the code,  $c_j$  is called `humcste` and defined in `constantes_mtc.f90`

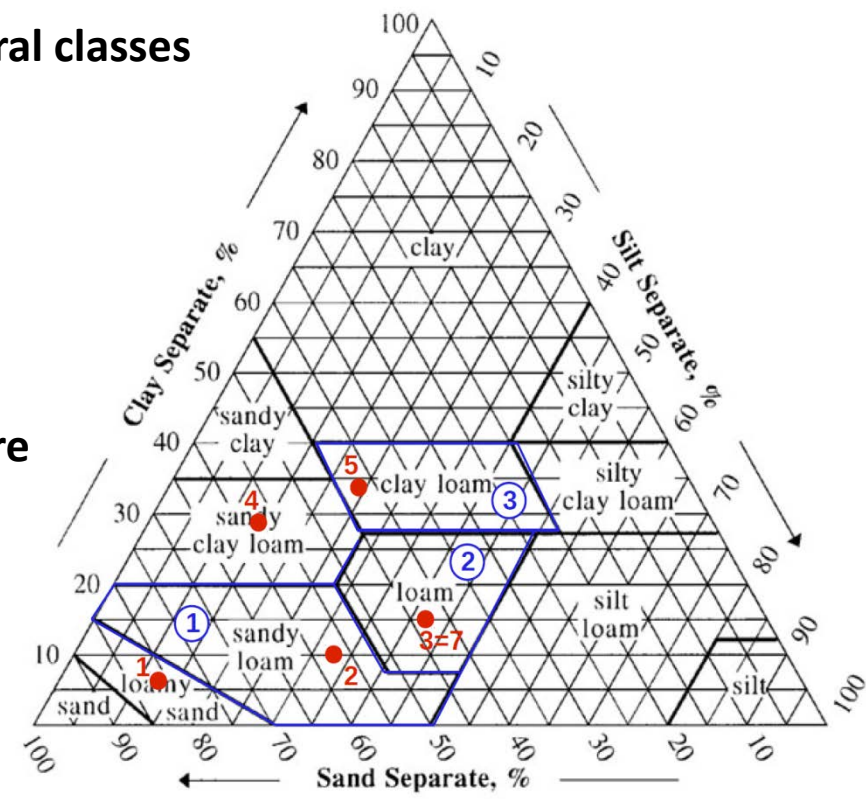
It can be « externalized », with default values depending on soil hydrology/depth

```
REAL(r_std), PARAMETER, DIMENSION(nvmc) :: humcste_cwrr = &
  & (/ 5.0, 0.8, 0.8, 1.0, 0.8, 0.8, 1.0, &
  & 1.0, 0.8, 4.0, 4.0, 4.0 /)
!! Values for dpu_max = 2.0
```

# The role of soil texture

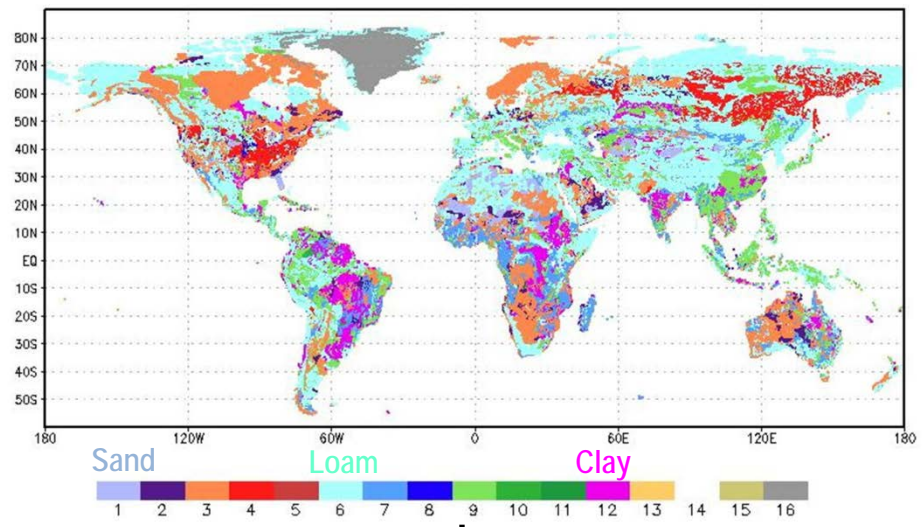
- In hydrol, the main soil properties are:  $\theta_s$   $\theta_r$   $K_s^{ref}$   $n$   $\alpha (= -1/\psi_{ae})$   $\theta_w$   $\theta_f$
- clay\_fraction is a parameter for stomate
- They are defined based on soil texture  
(in the real world, they can depend on other factors, as soil structure, OMC, etc.)
- **Soil texture is defined by the % of sand, silt, clay particles in a soil sample** (granulometric composition)
- **Soil texture can be summarized by soil textural classes**
- By default, ORCHIDEE reads texture from the 1°x1° map of Zabler (1986) **with 3 classes**
- Alternative soil map : 1/12° USDA map of Reynolds et al. (2000)
- **In each grid-cell, we use the dominant texture**

In red, the interpretation of the Zabler texture classes in ORCHIDEE.  
 In blue, the definition of the default three main textures in ORCHIDEE

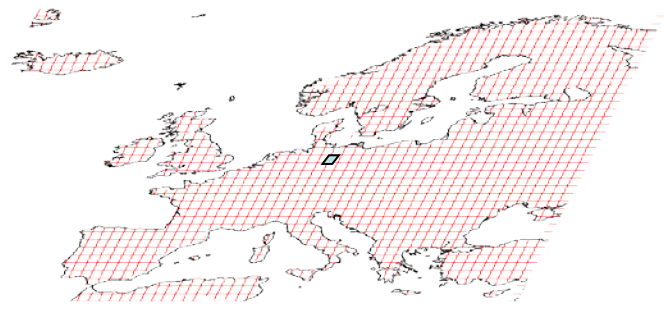


# The role of soil texture

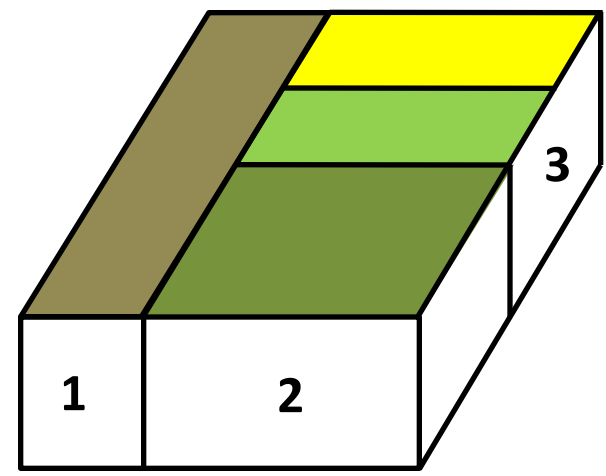
5' USDA texture map (Reynolds et al., 2000)



Dominant texture in each ORCHIDEE grid-cell:  
defining the hydraulic properties



Sub-grid scale heterogeneity:  
3 soil columns based on PFTs  
with independent water budget  
**but same texture**



- 1: Bare soil PFT
- 2: All Forest PFTs
- 3: All grassland and cropland PFTs



## The role of soil texture

- In hydrol, the main soil properties are:  $\theta_s$   $\theta_r$   $K_s^{\text{ref}}$   $m$   $\alpha=1/\psi_{ae}$   $\theta_w$   $\theta_f$

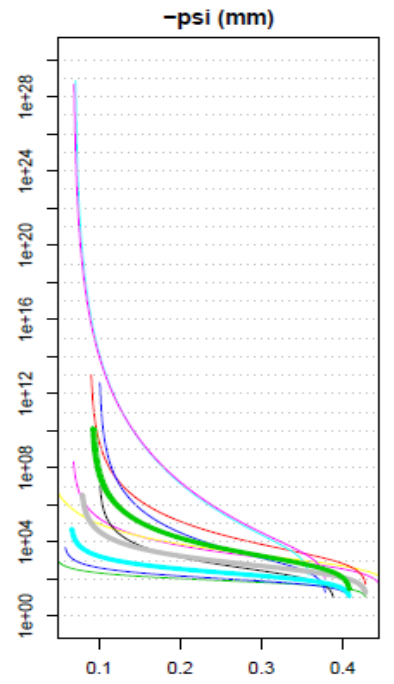
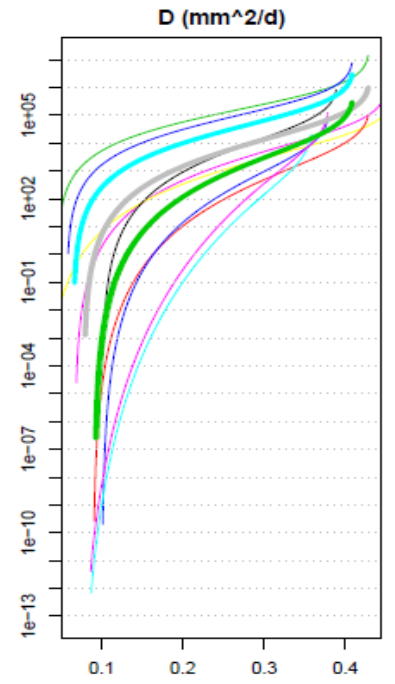
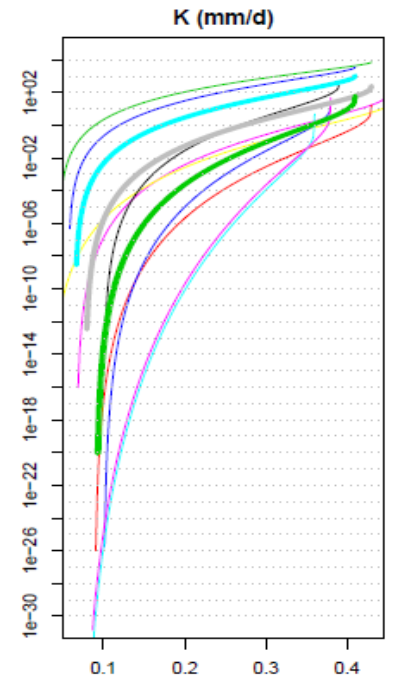
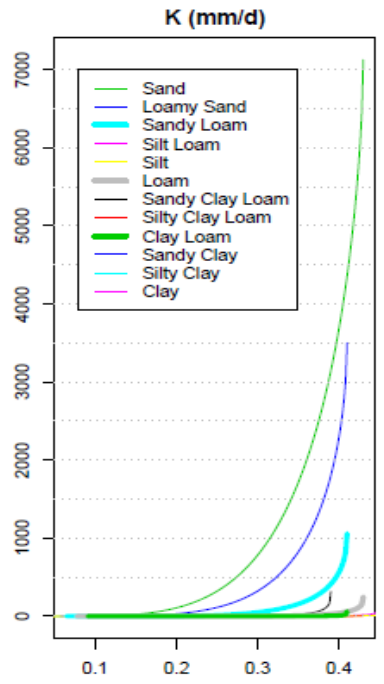
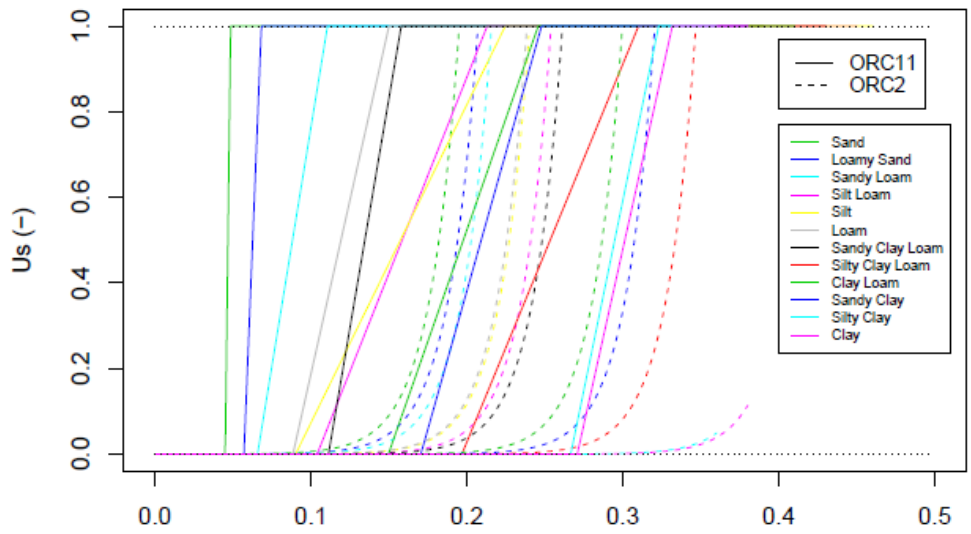
Their default values are defined in `constantes_soils`,  
with the suffix `_usda` or `_fao` (Zobler)

- They are defined based on soil texture  
(in the real world, they can depend on other factors, as soil structure, OMC, etc.)

### *Three ways of defining soil texture in `run.def`*

- Default keywords:** `SOILTYPE_CLASSIF = zobler`; `SOILCLASS_FILE = soils_param.nc`
- For Reynolds : `SOILTYPE_CLASSIF = usda` ; `SOILCLASS_FILE = soils_param_usda.nc`
- `IMPVEG=y`, `IMP_SOIL=y`, `SOIL_FRACTION = (x,y,z, etc.)`
  - x,y,z are areal fraction allocated to the soil textural classes defined by your selected map
  - x,y,z are not % sand, silt, clay defining your soil's texture, despite the fact that this option is primarily intended for OD simulations
  - to get the soil properties of one texture class, set `SOIL_FRACTION = (1,0,0, ...0...)`, and use the externalization to redefine the 1st value of the vectors defining soil properties

# The role of soil texture

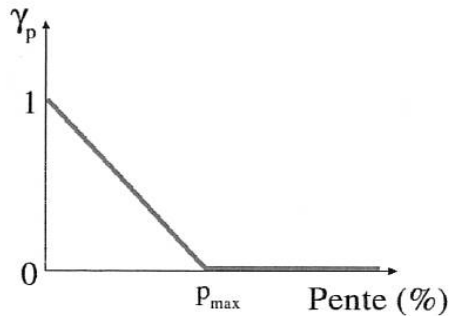


# Slope and reinfiltration

Reinfiltration fraction =  $\gamma_p$

$$R_s = (1 - \gamma_p) R_s^{\text{pot}}$$

Based on slope

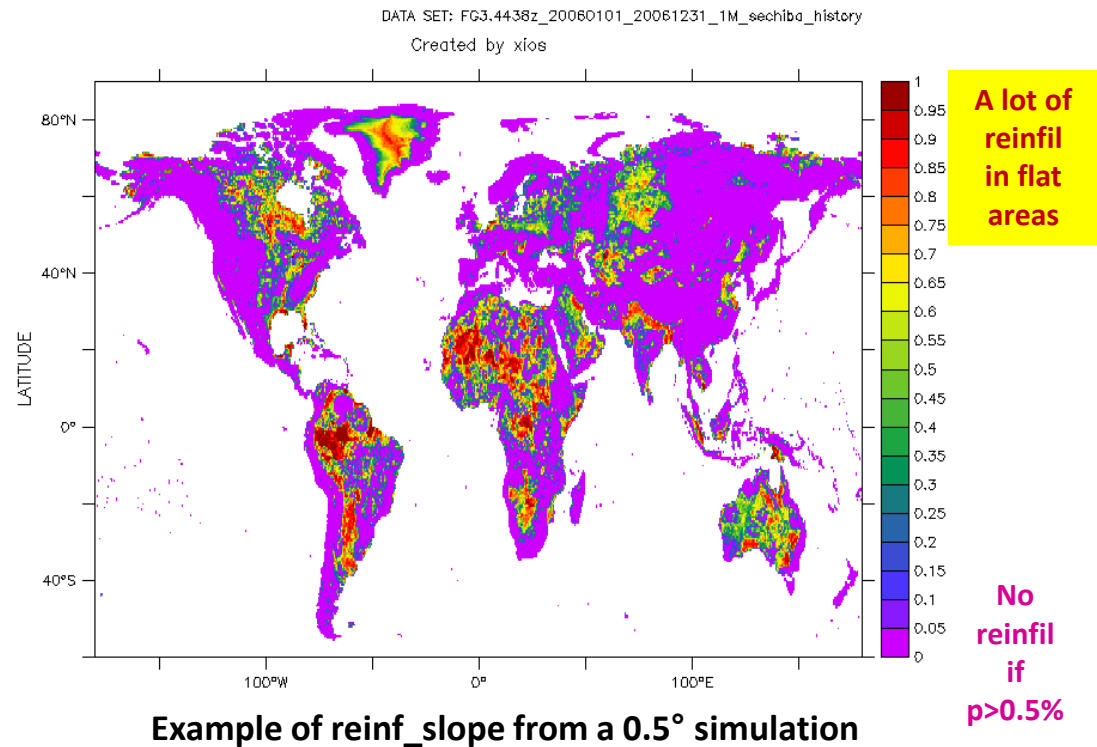


1. Slope is read at the resolution of  $0.25^\circ$   
(cartepente2d\_15min.nc)

2.  $\gamma_p$  is calculated at the resolution of  $0.25^\circ$   
$$\gamma_p = 1 - \min(1, p/p_{\max})$$

3.  $\gamma_p$  is averaged at the resolution of ORCHIDEE

*In run.def, you can change:*  
 $p_{\max}$ : SLOPE\_NOREINF = 0.5 (%)  
(but 0 may not work to cancel reinfiltration!)



Example of reinf\_slope from a  $0.5^\circ$  simulation

# Soil hydrology in a nutshell

- **During a time step, the soil hydrology scheme :**
  - Updates the soil moisture
  - Calculates the related fluxes (infiltration, surface runoff, drainage)
  - Calculates the water stresses for transpiration and soil evaporation of the next time step
  - Calculates some soil moisture metrics for thermosoil and stomate
- **The equations can be complex, but the parametrization is intended to work without intervention**
  - Default input maps are defined in COMP/sechiba.card
  - Defaults parameters are defined in PARAM/run.def and code
  - Lot of debugging over the past years
- **You can adapt the behavior of the scheme:**
  - Easy : change externalised parameters in PARAM/run.def
  - A bit less easy: use different input maps (you need to comply to the format)
  - More difficult: change the code (welcome to orchidee-dev!)

# Soil hydrology in 44 pages

The hydro1 module of ORCHIDEE: scientific documentation  
[rev 3977] and on, work in progress, towards CMIP6v1

A. Ducharne

with C. Ottlé, F. Maignan, N. Vuichard, J. Ghattas, F. Wang, P. Peylin, J. Polcher,  
M. Guimberteau, P. Maugis, S. Tafasca, A. Tootchi, A. Verhoef, H. Mizuochi

November 30, 2017

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### More details on the Wiki

[http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/eqs\\_hydrol.pdf](http://forge.ipsl.jussieu.fr/orchidee/attachment/wiki/Documentation/eqs_hydrol.pdf)

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**Thank you for your attention**  
**Questions ?**

