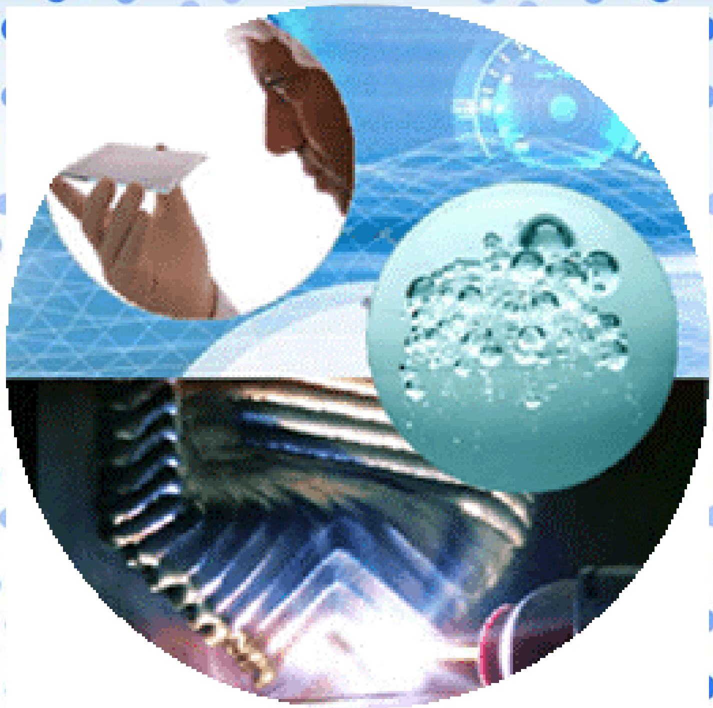


Dynamic of tritium in soil water

Based on a 2-FUN deliverable done by Philippe Ciffroy

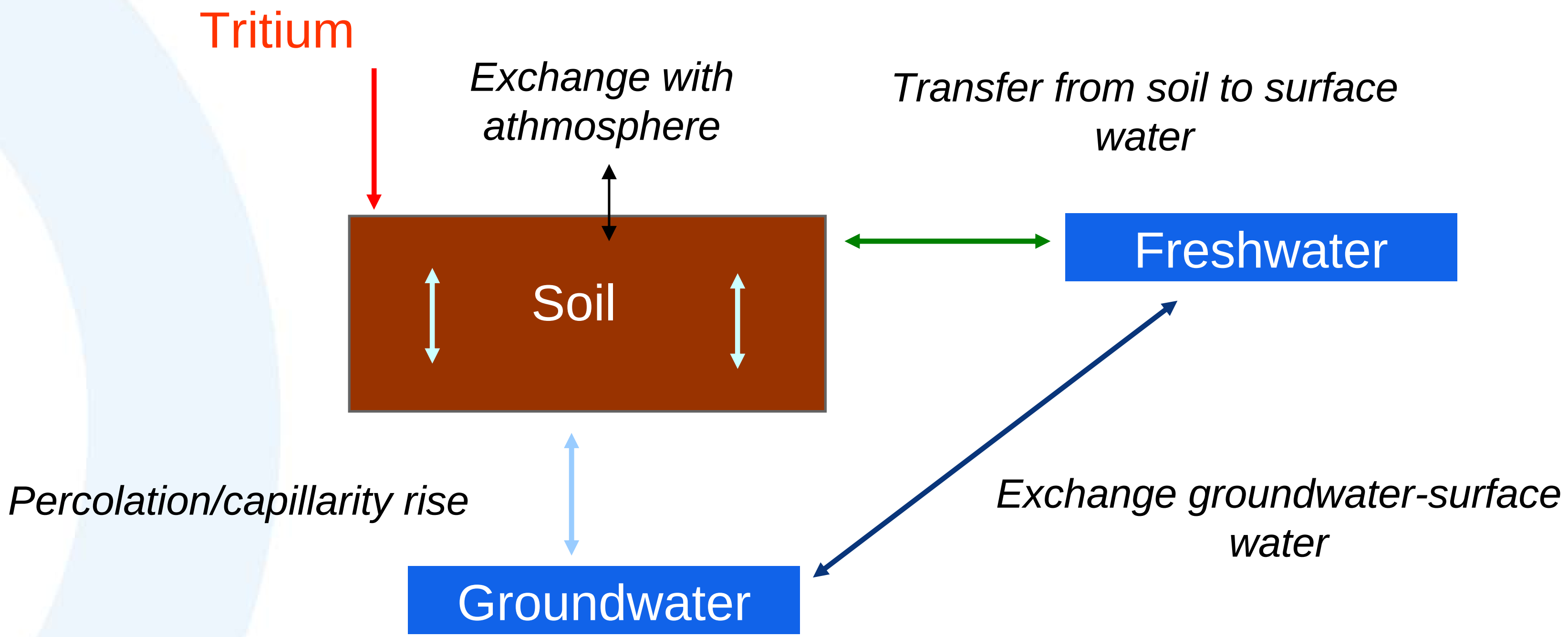
The models which were reviewed during the 2 FUN project :

AQUATOX - US EPA - 2004	Ecological food-web freshwater model kinetically describing transfer of chemicals in various abiotic and biotic compartments. Endpoint: ecological adverse effects
CALTOX - California Un.	Spreadsheet mass balance steady-state box model. The exposure model encompass 23 exposure routes.
CemoS - DTU - 1998	Mass balance steady-state box model included in the CemoS package
OURSON - EDF - 2006	Dynamic transfer initially developed for simulating the human exposure to radionuclides and metals discharged in freshwater. Extended to metal discharges in the atmosphere and organic discharges in rivers
QWASI (and derived models QMX, DynA) - Mackay (1986) to Warren (2007)	Model simulating the steady-state chemical concentration in a lake or river segment. It adopts a steady-state fugacity approach, each transfer being described by constant exchange rates.
SimpleBox - RIVM - 1996	Steady-state multimedia model incorporated in the EUSES system, recognized at European for assessing the distribution of (essentially organic) pollutants in the environment at regional scale.
TRIMFate - US EPA - 2002	Compartmental mass balance model providing exposure estimates for ecological receptors (plants and animals), in particular in freshwater systems. The output concentrations from TRIM.FaTE can also be used as inputs to a human ingestion model.
XtraFood -VITO - 2006	Chain model for the analysis of contaminant in primary food products

+ PRZM and PEARL (models dedicated to pesticides)

Dynamic of tritium in soil

- Question: What is the dynamic of tritium after deposition on soil?



Question 1 : Transfer from soils to surface waters: wash-off (1/4)

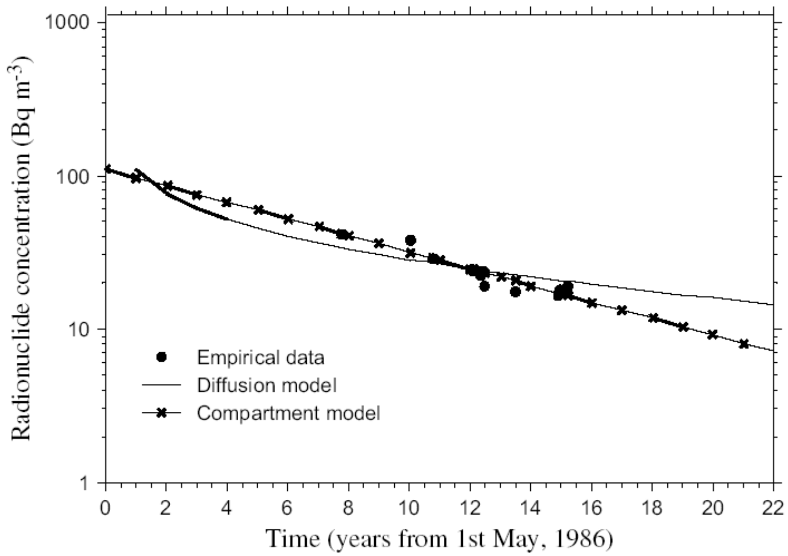
Definition :

Wash-off = runoff of contaminants dissolved in soil pore water + erosion of contaminated soil particles from watersheds

Why?

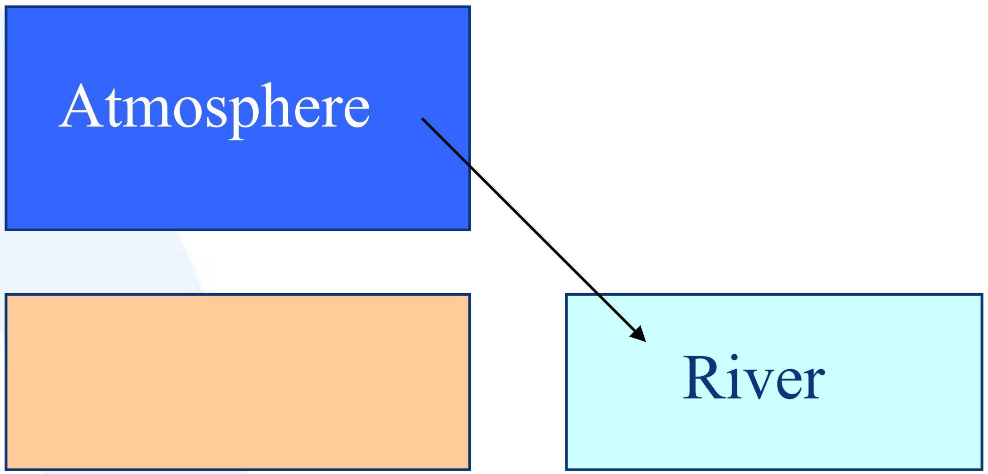
Significant secondary input into freshwaters because these latter collect water and particle fluxes from potentially wide areas, especially during rainfall

^{137}Cs in water of Lake Monterosi. Comparison experimental. data/model predictions



Question 1 : Transfer from soils to surface waters: wash-off (2/4)

1. Permanent transfer function (e.g. SimpleBox)



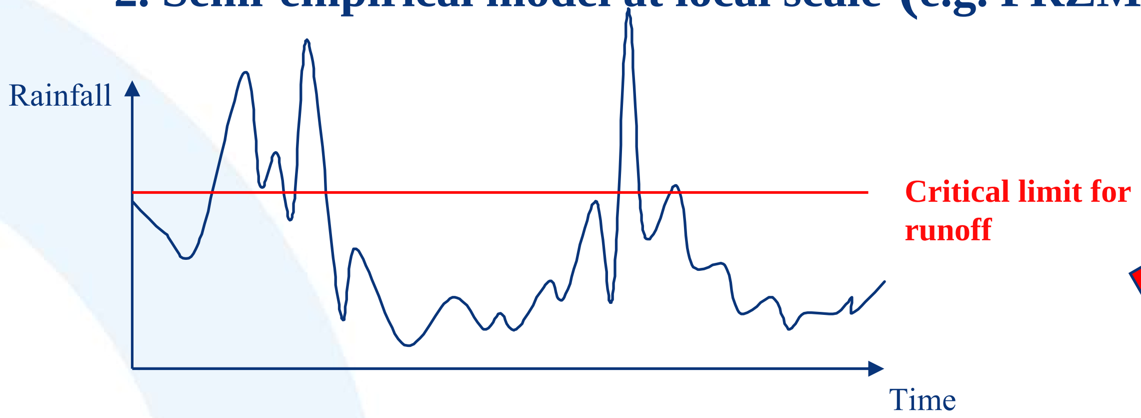
$$\text{Runoff} = \frac{FT_{atm-river}.\text{Rain}}{K_{d,soil}}$$

✓*$FT_{atm\text{-}river}$: fraction of rain water running off from soil to water*

How to estimate the fraction of rainfall running to rivers/lakes (no clear justification of $FT_{atm\text{-}river}$ default values)?

Question 1 : Transfer from soils to surface waters: wash-off (3/4)

2. Semi-empirical model at local scale (e.g. PRZM)



$$\text{Runoff\_depth}(t) = \begin{cases} 0 & \text{if } P(t) \leq P_{limit} \\ f(P(t), CN) & \text{if } P(t) > P_{limit} \end{cases}$$

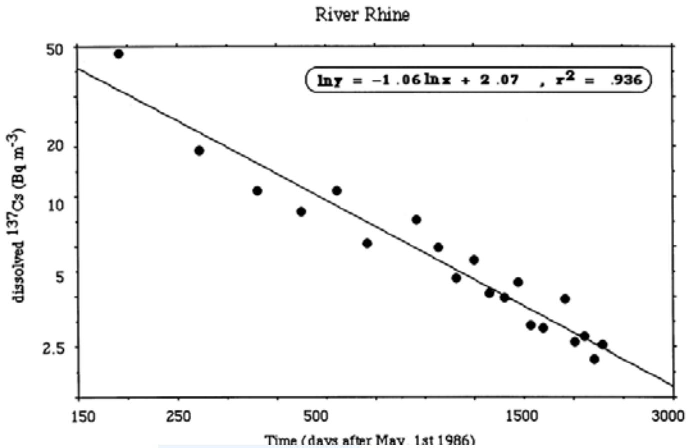
✓*Plimit : Limit rain intensity*

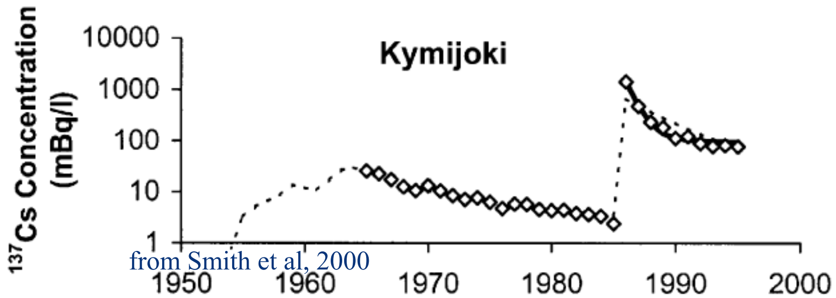
✓*CN: Curve number parameter depending on landscape caracteritics*

Reliable at local scales (e.g. field with well-known land use coverage, slope, etc)
Reliable for short rainfall events
BUT
Poorly applicable at global watershed scales
Require meteorological datasets at a high temporal resolution

Question 1 : Transfer from soils to surface waters: wash-off (4/4)

3. Dynamic transfer function at watershed scale (e.g. OURSON) : this approach was used in radiological models, the calibration of transfer function being possible after the Chernobyl accident for a wide range of European rivers.





from Smith et al, 2000

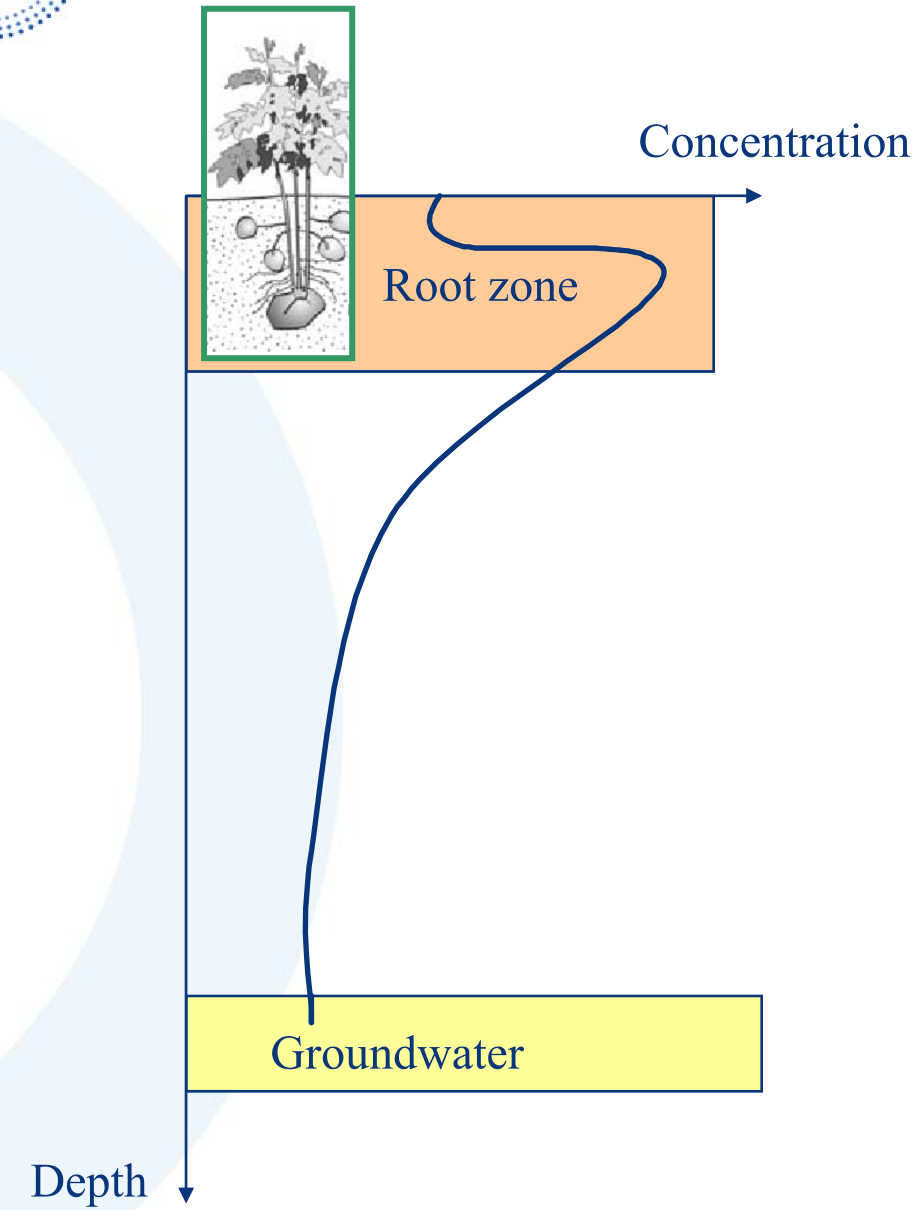
$$\Phi_{wash-off}(t) = D_{soil}(t_0).S_{watershed}.\lambda_{wash-off}(t)$$

- ✓*Dsoil: Atmospheric deposition*
- ✓*$S_{watershed}$: Surface of the watershed*
- ✓*Lamda_wash_off: loss rate constant*

Reliable at watershed scales

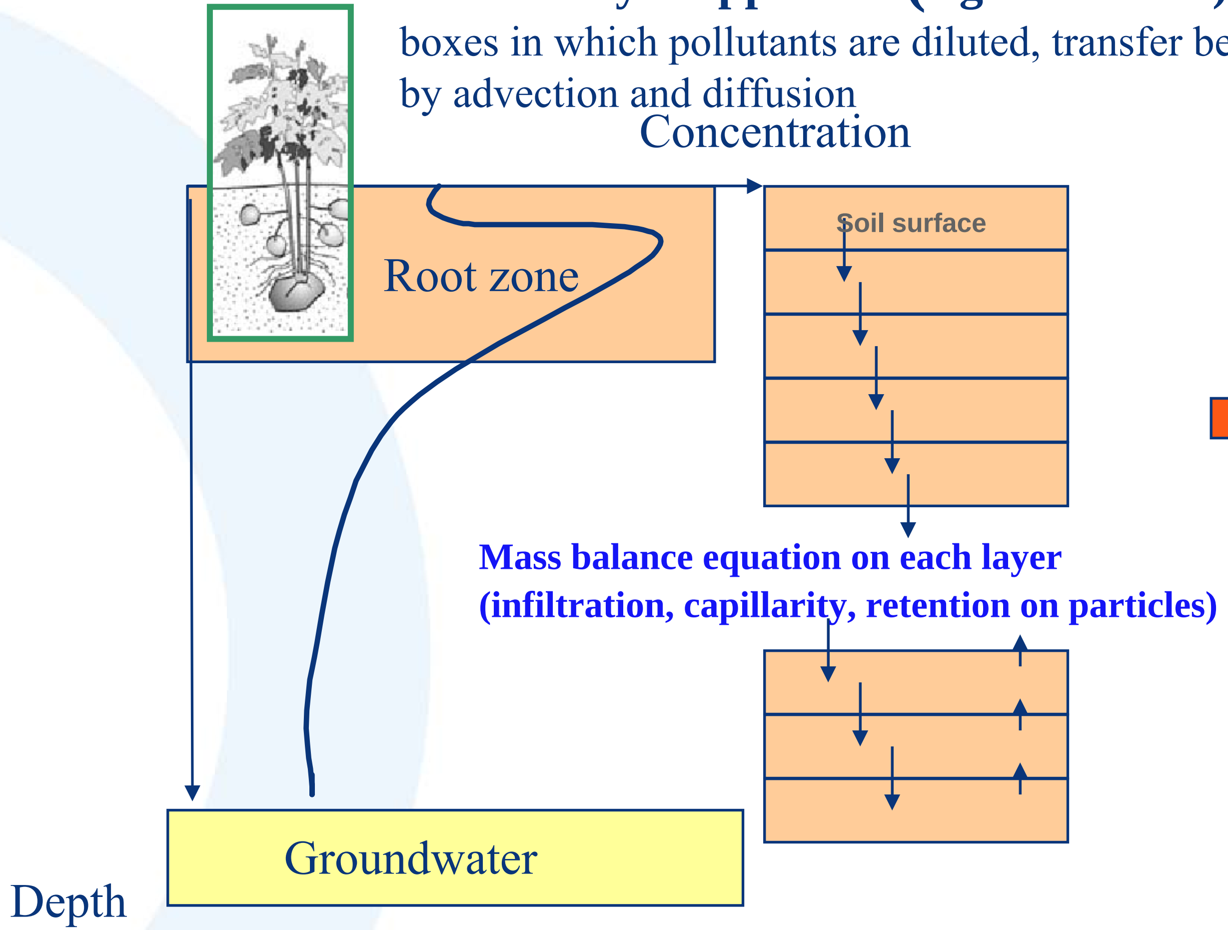
Experimental data exist for several contaminants presenting different geochemical behaviours (mobile and immobile RNs)

Question 2 : Dynamics in the soil profile (1/6)



Question 2 : Dynamics in the soil profile (2/6)

1. Multi-layer approach (e.g. OURSON) : succession of homogeneous boxes in which pollutants are diluted, transfer between these latter are governed by advection and diffusion



$$N = \frac{v_w . L}{2D}$$

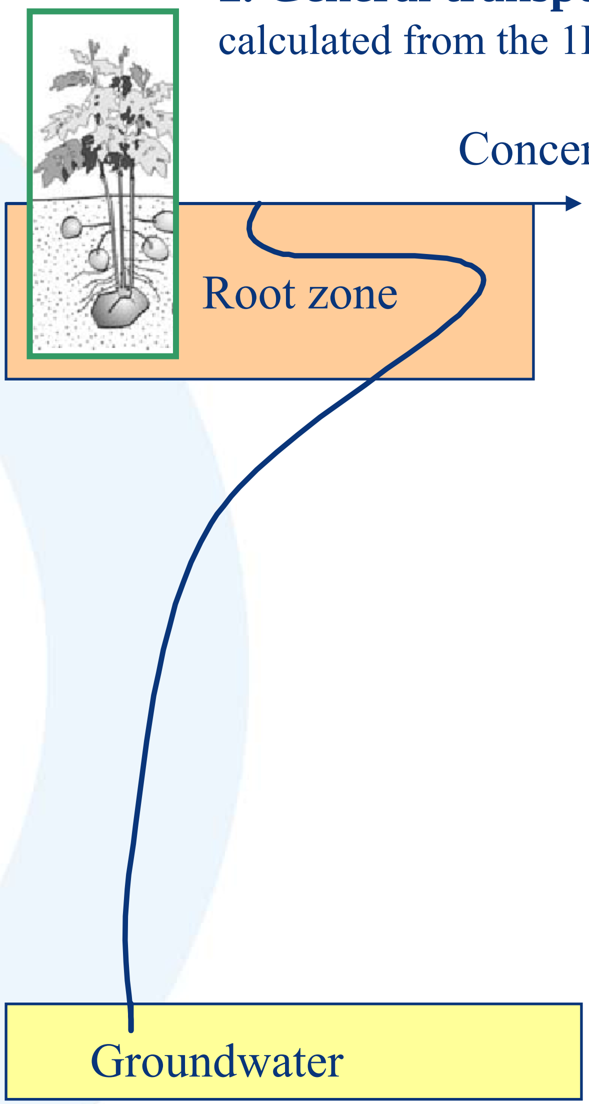
(e.g. Kirchner, 1998)

- ✓ *N: Number of compartiments*
- ✓ *Vw: the pore water advection velocity*
- ✓ *L: the total soil depth*
- ✓ *D: the diffusion coefficient*

Need of a reliable definition of the layer in interaction with atmosphere
Need a flexible definition of the number of compartiments

Question 2 : Dynamics in the soil profile (3/6)

2. General transport equation : concentration of the pollutant in soil calculated from the 1D general transport equation in soil

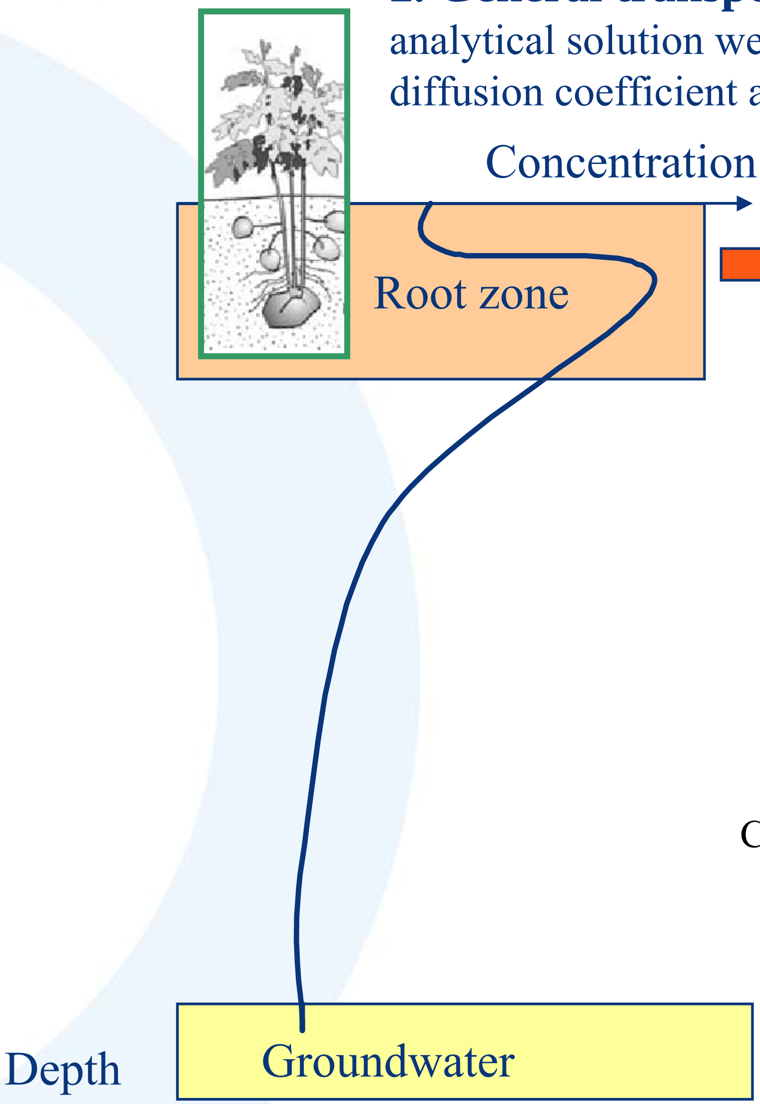


$$R.\frac{\partial C}{\partial t} = -v_e.\frac{\partial C}{\partial z} + D_e.\frac{\partial^2 C}{\partial z^2} - kC$$

- ✓ *R :retardation factor = 1 for tritium*
- ✓ *Ve: pore water advection velocity*
- ✓ *De: diffusion coefficient*
- ✓ *k : rate constant for contaminant degradation*

Question 2 : Dynamics in the soil profile (4/6)

2. General transport equation (additivity assumption) : several analytical solution were proposed assuming uniform soil properties, constant diffusion coefficient and flow velocity…



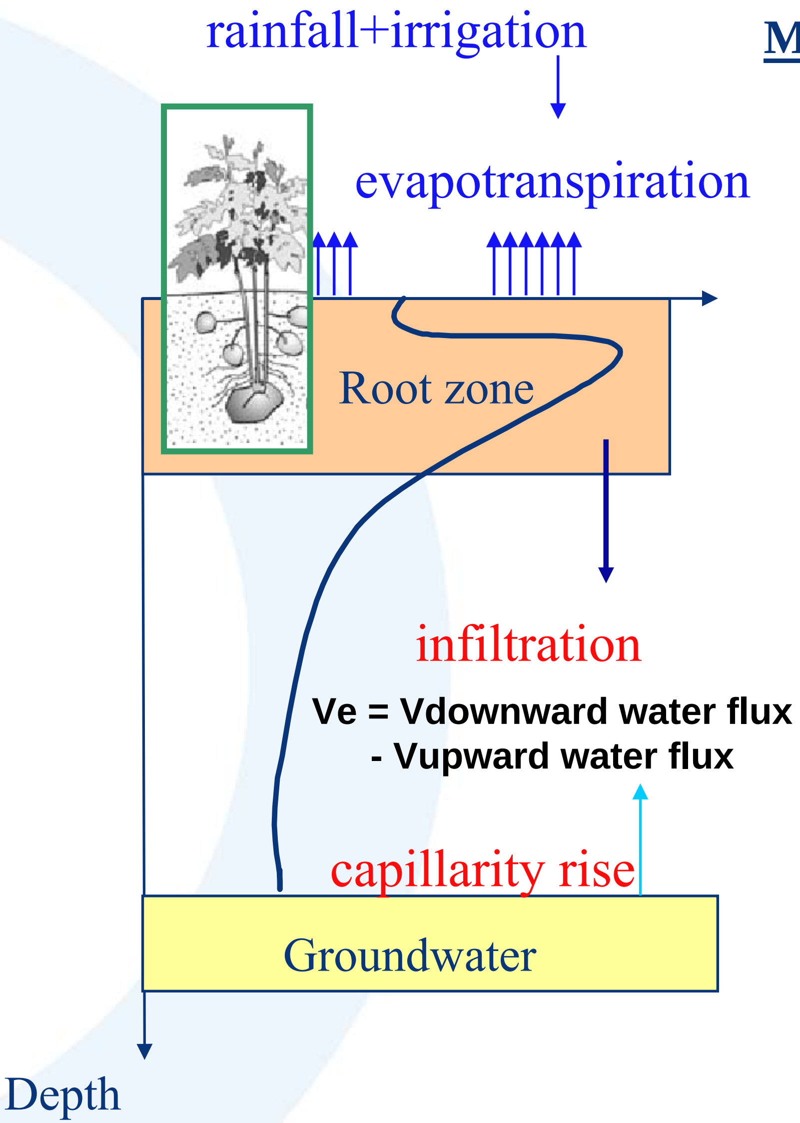
For pulse input (Dirac)

$$C(z,t) = \frac{m_0}{\sqrt{4\pi D_e^* t}}.\exp\left(-\frac{\left(z - v_e^* t\right)^2}{4D_e^* t}\right).\exp(-k^* t)$$

For continuous input (superposition of pulse inputs)

$$C(z,T) = \int_{t=0}^{T} \frac{m_{T-t}}{\sqrt{4\pi D_e^*(T-t)}} \exp\left[-\frac{\left(z - v_e^*(T-t)\right)^2}{4D_e^*(T-t)}\right] \exp\left(-k^*(T-t)\right) dt$$

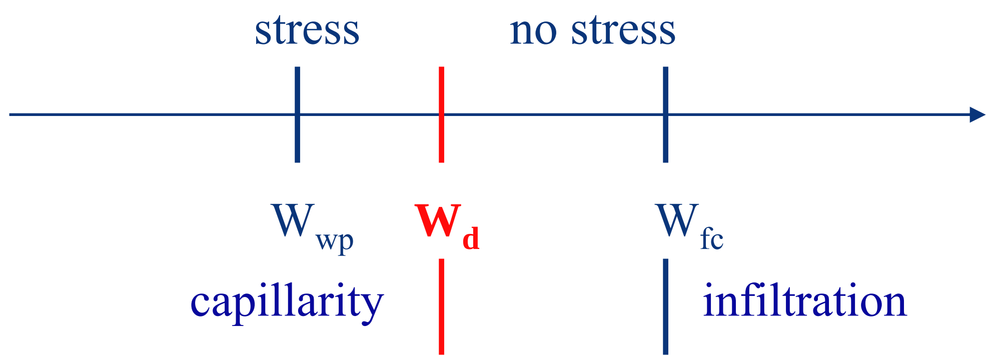
Question 2 : Dynamics in the soil profile (5/6)



Mass balance of water content in the soil

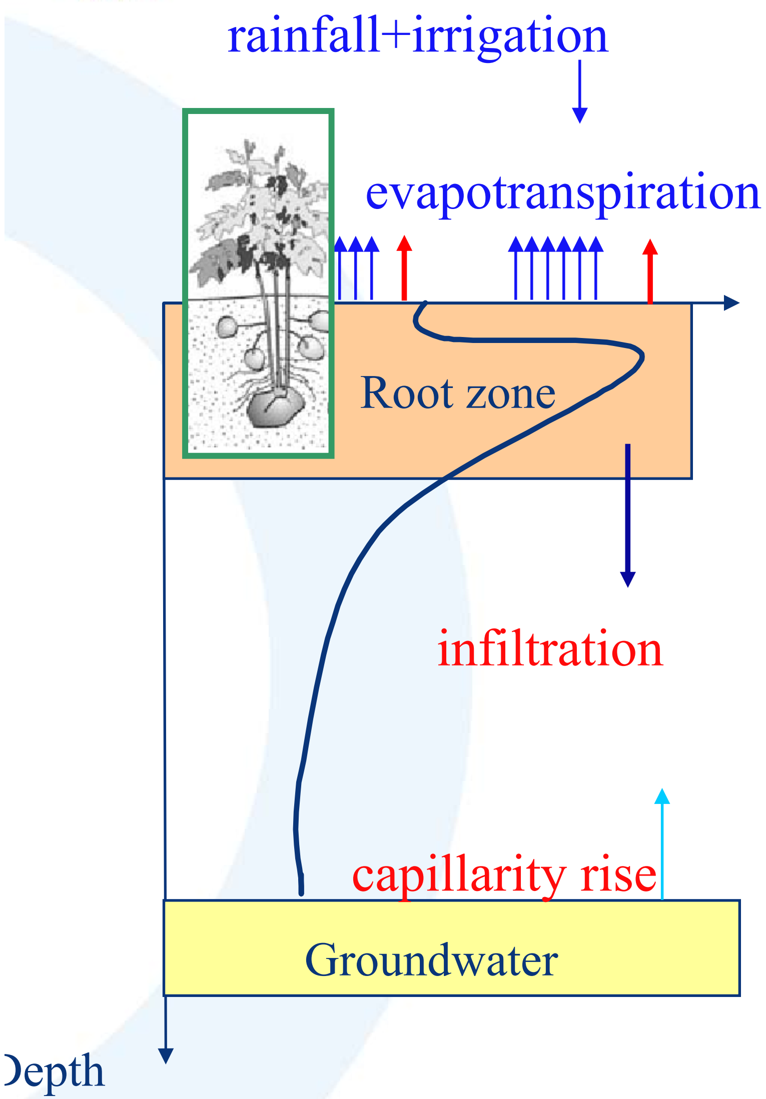
$$\frac{dW}{dt} = P_e + Irr + G_c - ET_a - D_r$$

- ✓ *Pe: effective precipitation*
- ✓ *Irr: dayly irrigation rate*
- ✓ *Gc: Groudwater contribution to water storage*
- ✓*Eta: actual evapotranspiration*
- ✓*Dr: deep percolation loss rate*



- ✓ *Wfc: soil water storage at field capacity*
- ✓ *Wwp: soil water storage atwitlting point*
- ✓ *Wp: soil water storage corresponding to the depletion fraction for no stress*

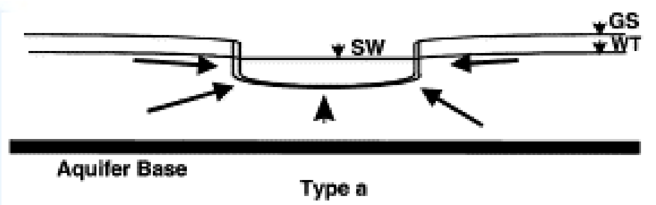
Question 2 : Dynamics in the soil profile (5/6)



Additional question for tritium ? Tritium follows its own gradient concentration from soil to atmosphere

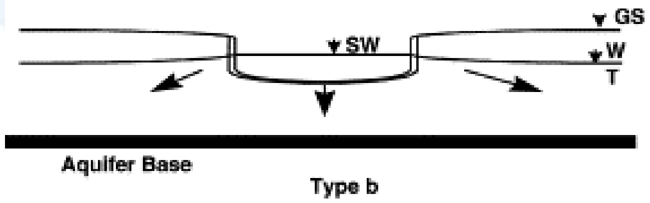
?? Ideas of participants

Question 3 : Exchanges groundwater-surface water (1/2)

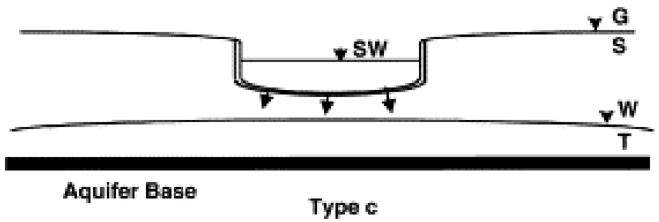


Connected gaining stream : the groudwater table is higher than the water level in the stream

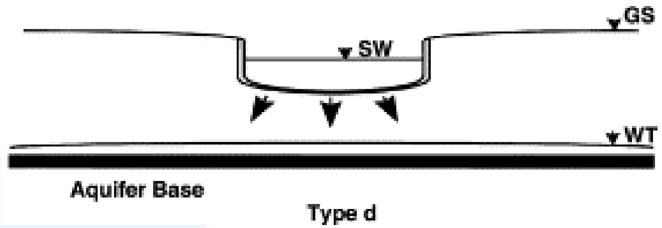
TRIMFATE: Recharge cst



Connected loosing stream : the groudwater table is higher than the water level in the stream



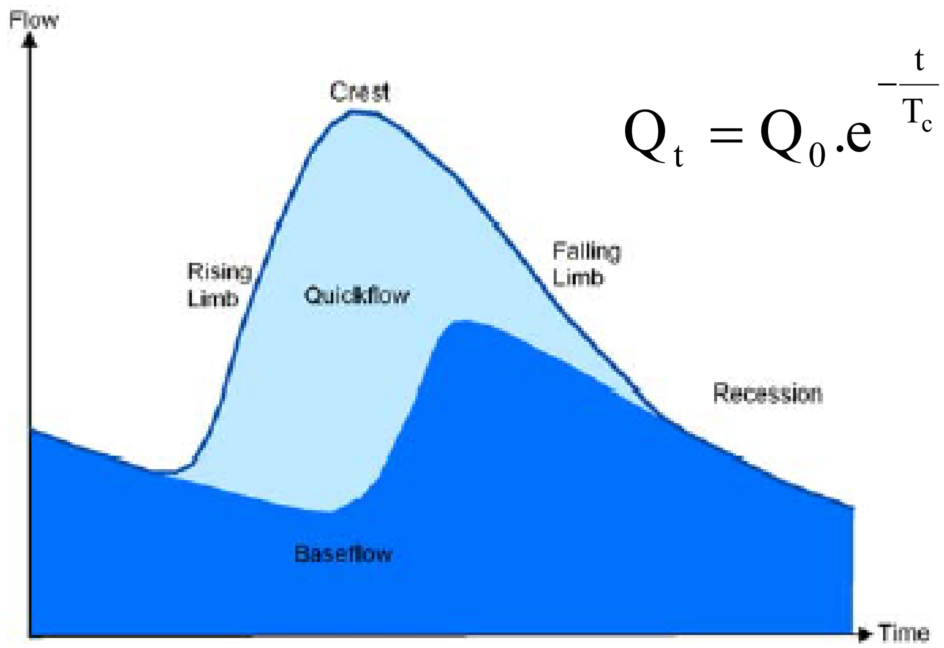
No hydraulic connection – superficial water table



No hydraulic connection – deep water table

Question 3 : Exchanges groundwater-surface water (2/2)

How to parameterize recharge from groundwater to surface waters?



$$Q_t = Q_0 . e^{-\frac{t}{T_c}}$$

T_c : residence time or turnover time of the groundwater system defined as the ratio of storage to flow

Analysis of the Flood hydrograph (time series record of water flow of the investigated river) can indicate the magnitude of the contribution of the groundwater