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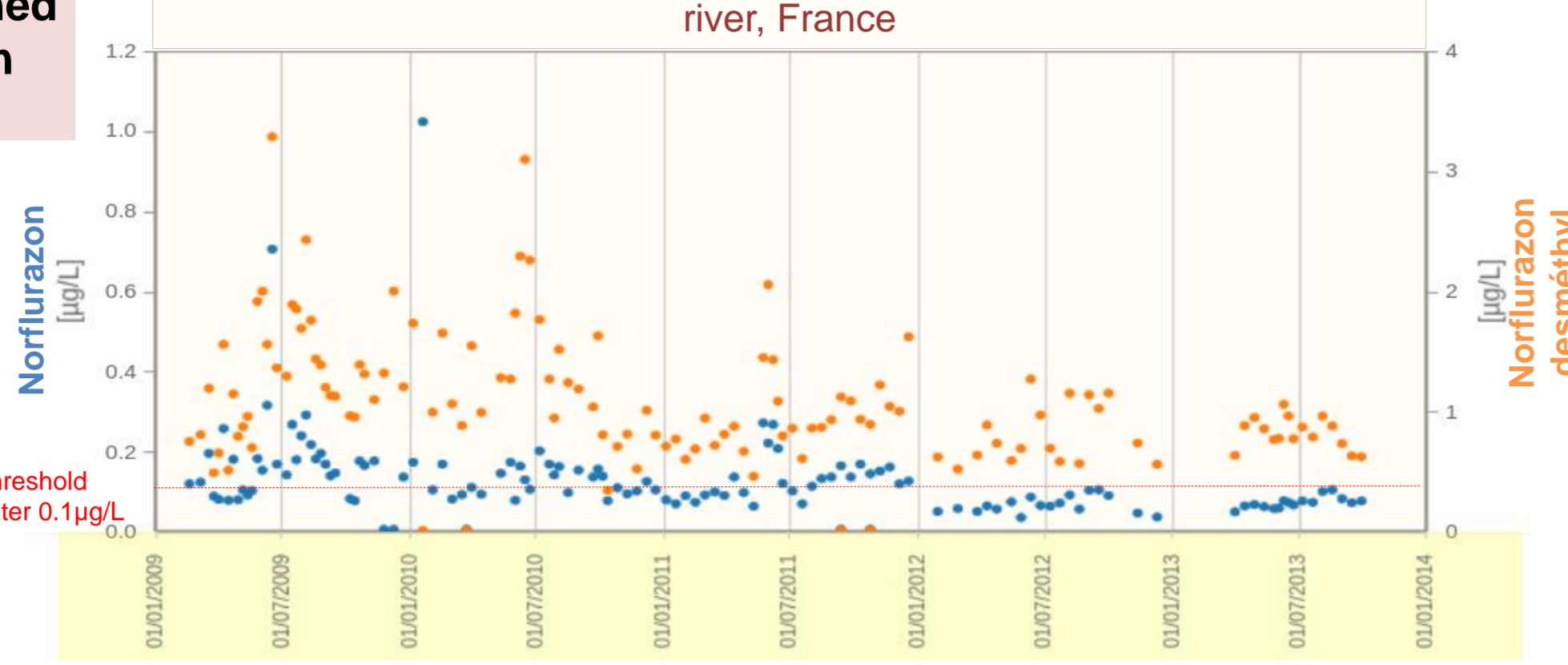
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# Modeling transfer of pesticides and their degradation products in shallow groundwater by taking into account variable residence time

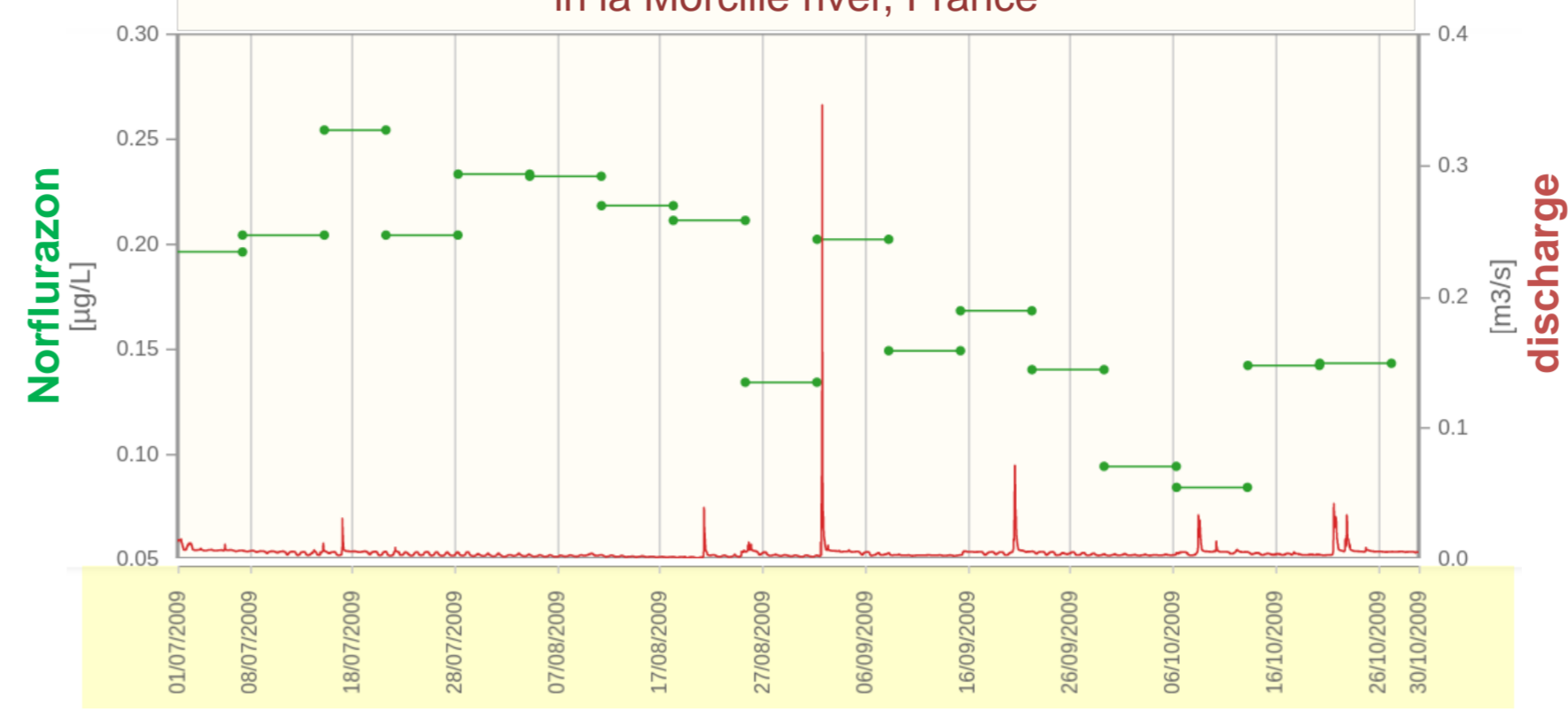
## Context

Norflurazon use has been banned since 2003 in France



→ Reducing pesticide loads or banning the use of some active substances would not result in **immediate** decrease in their concentrations because of the long memory of the catchments.

Time averaged concentrations of Norflurazon during low flows, in the Morcille river, France



→ These results show the impact of **surface/groundwater interactions** on the stream quality as in low flow conditions, the river is mostly fed by groundwater.

## Objective

Our objective is to develop a groundwater module to better simulate the transfer of pesticides and their degradation products in hard rock aquifers

## Based on 3 main assumptions

1- Strong variations of water table in hard rock aquifers might have significant impact on remobilizing pesticides

• A **physically based approach** is assumed necessary to characterize the groundwater dynamics and to take into account its impact on pesticide transport.

2- Landscape elements are assumed to have a less significant influence on underground flows comparing to runoff or subsurface flows

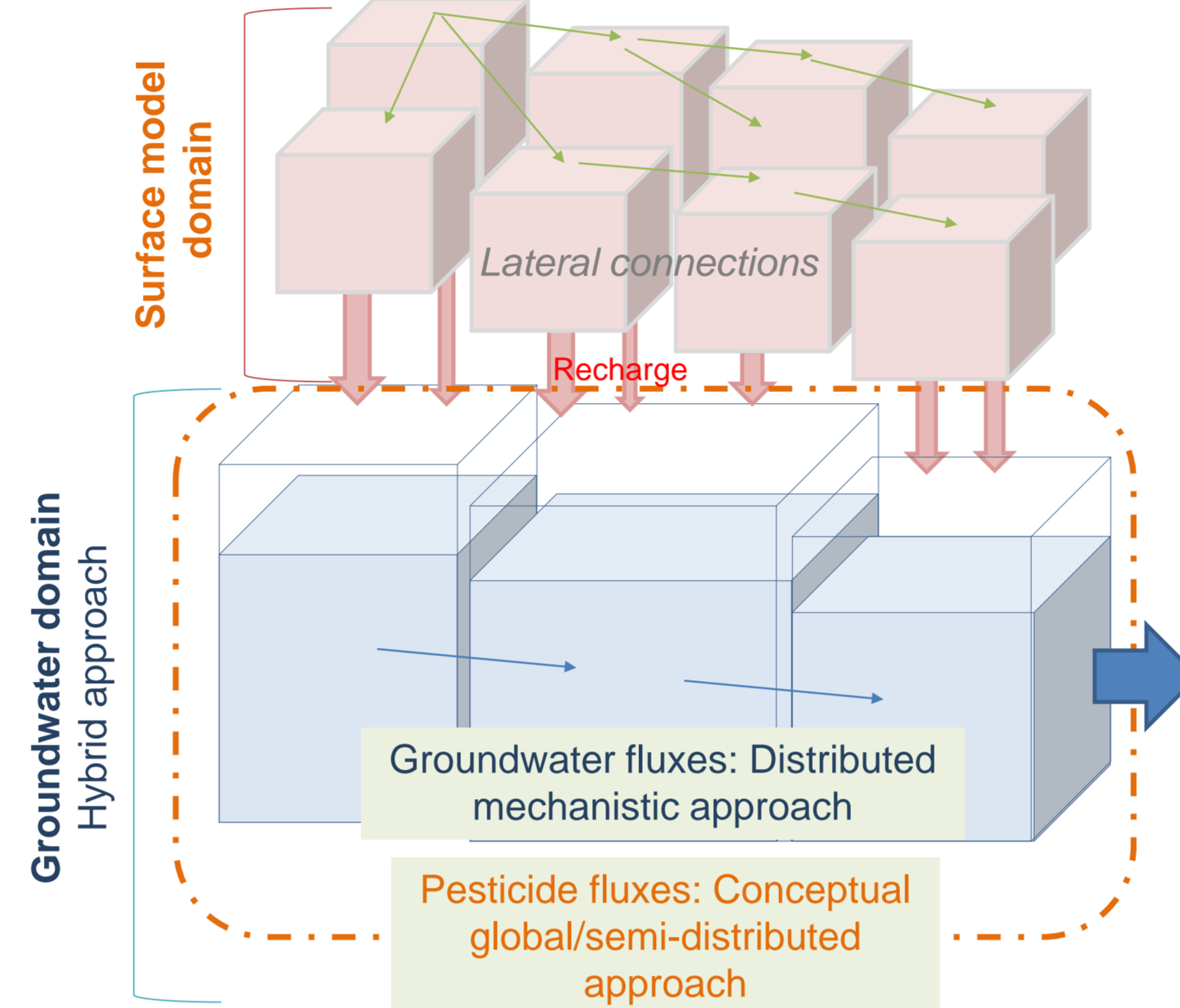
• A **Roughly distributed approach** is chosen to discretize the groundwater domain.

3- The time that water spends in the aquifer influences significantly pollutant fate

• A **conceptual approach** based on residence time distribution particularly on the **storage selection functions** is chosen to reproduce the solute dynamics in the aquifer.

## Model structure

Coupled to a distributed model (Rouzies & al, 2019) that represents water and pesticide transfer in surface and subsurface

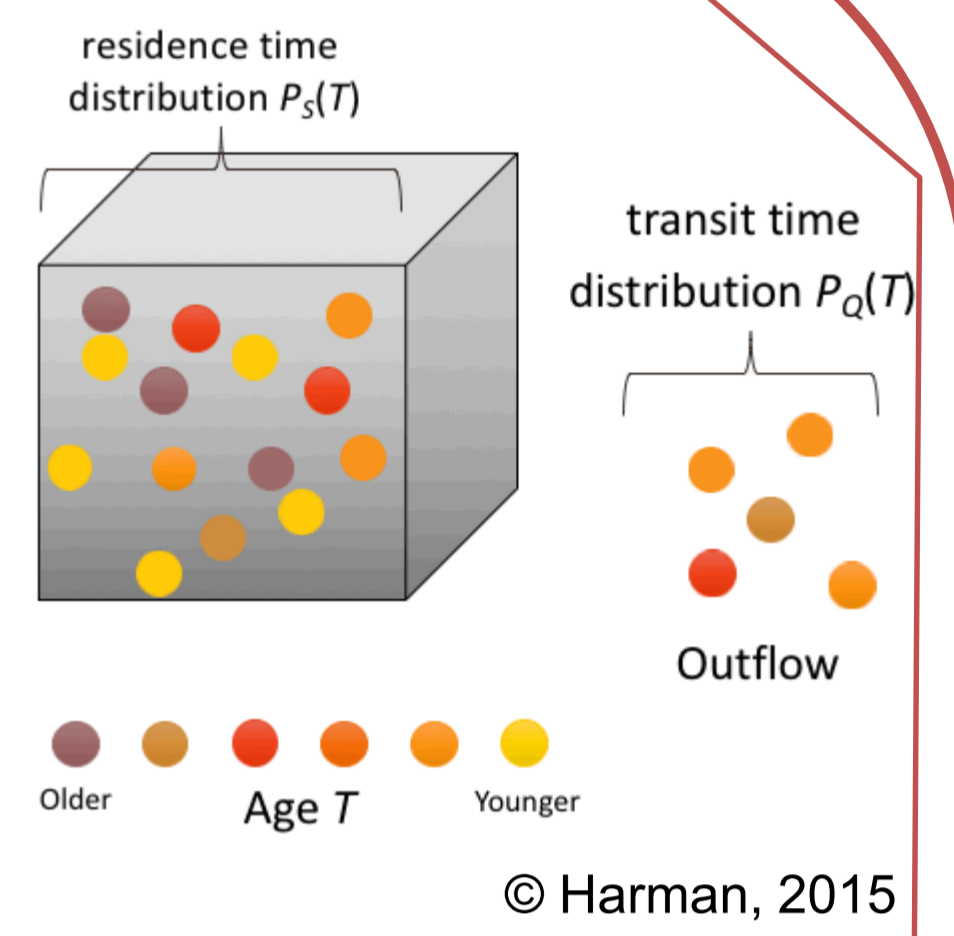


## Water age concepts:

$p_s(T, t)$  is the probability that water that has entered the system in the past is still retained in the storage

$p_Q(T, t)$  is the probability of water that entered the catchment in the past and that is leaving it at a given moment.

$w_Q(T, t)$  is the storage selection function defined as  $\frac{p_Q(T, t)}{p_s(T, t)}$  (Botter & al, 2011).



## Solute transport formulation based on transit time distribution (Botter & al, 2010):

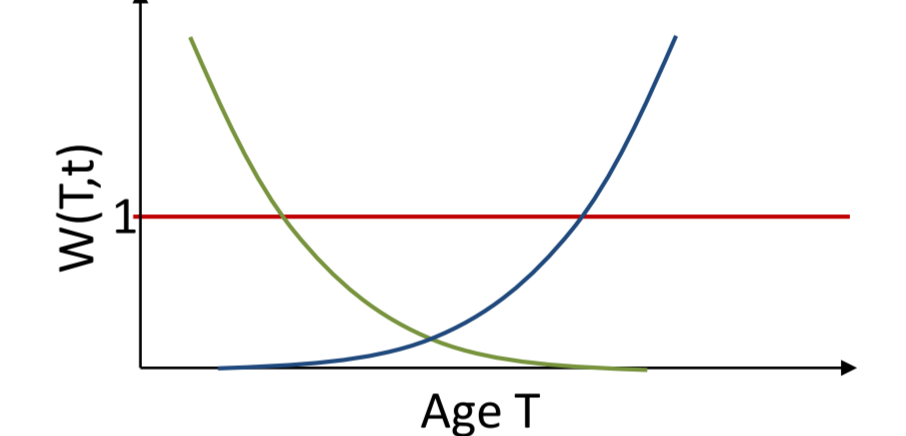
Assuming a SAS function, we can compute residence and transit time distributions and thus deduce solute concentrations:

$$C_Q(t) = \int_0^{\infty} C_R(t-T)(1 - e^{-r_d T})e^{-r_s T} p_Q(T, t) dT$$

Where:  $C_R$  &  $C_Q$  are respectively the input and output average solute concentrations.

$r_d$  &  $r_s$ : degradation and sorption kinetic rates.

Some Storage Selection function shapes  
Random sampling  
Young water preference  
Old water preference



## Groundwater fluxes simulation:

One dimensional finite difference model based on Darcy's equation

Saturated zone simulation only

The groundwater/subsurface interactions due to **water table rise** are explicitly taken into account

## Pesticide transfer simulation : the Storage Selection function approach

SAS functions describe how systems **store, mix** and **release** water and solutes. The choice of the SAS shape depends on our understanding to catchment behaviors

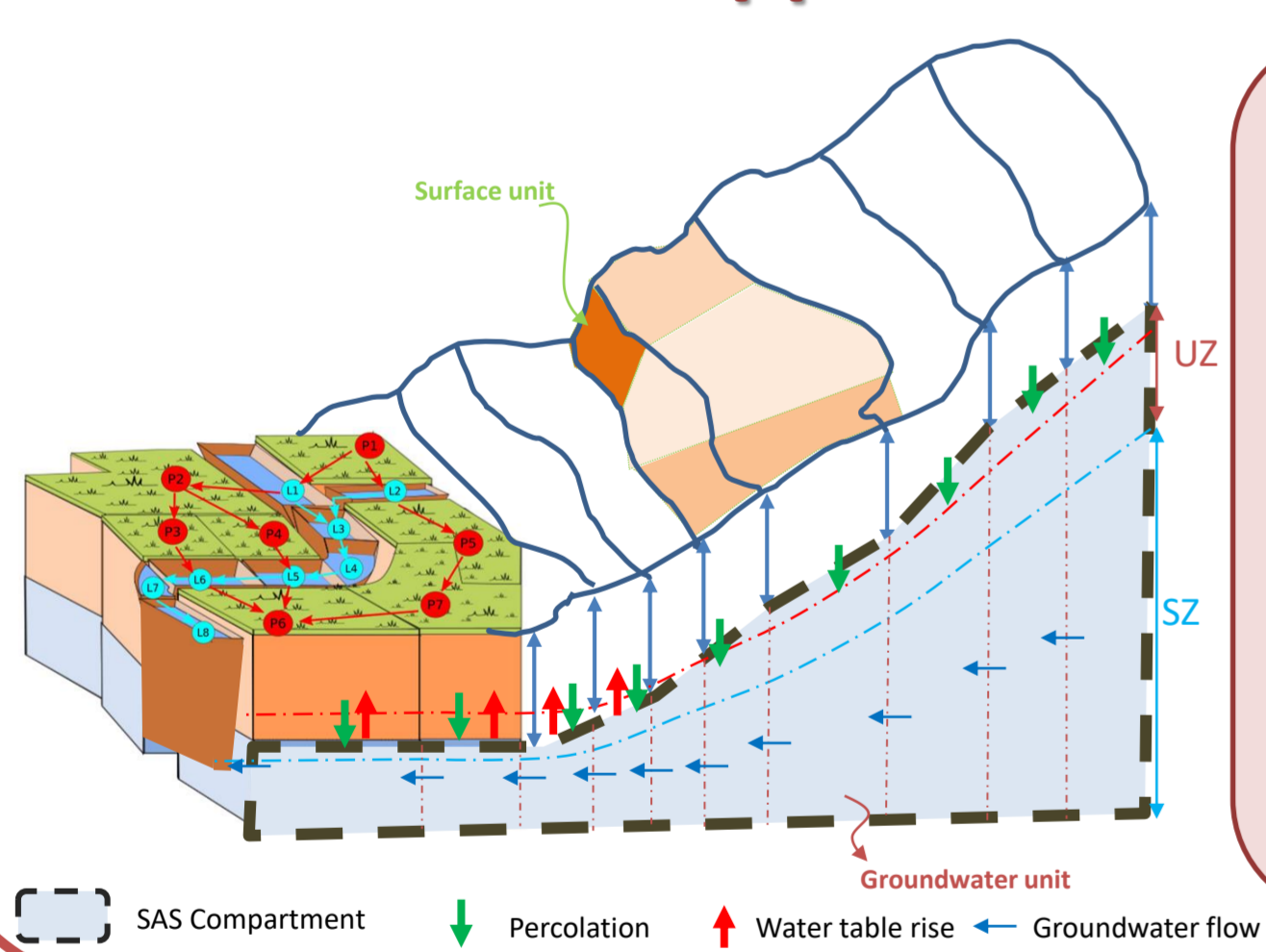
## MODELLING APPROACH

## SCENARIOS

## STUDY BASINS & DATA

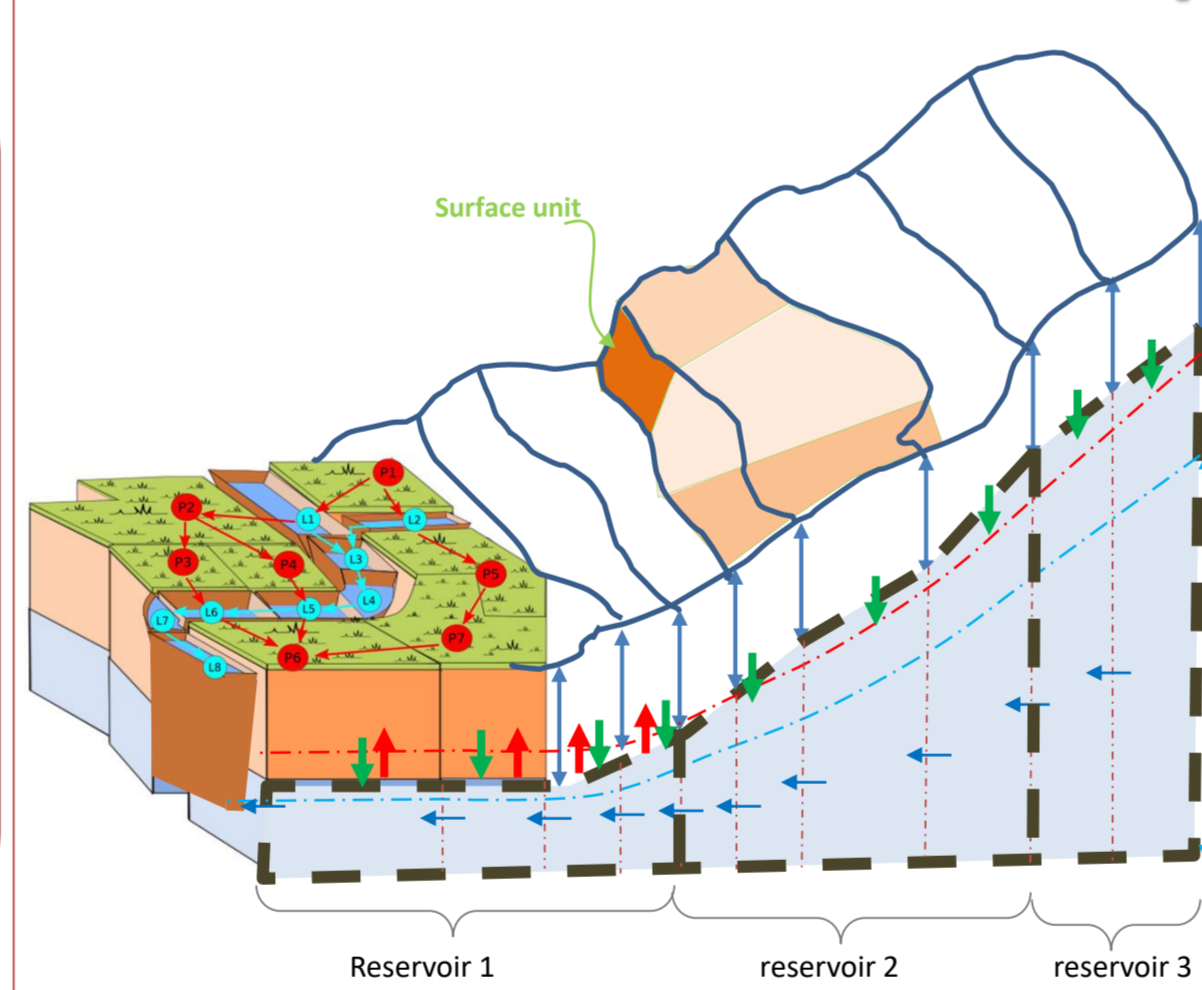
## CONCLUSION

### Global approach



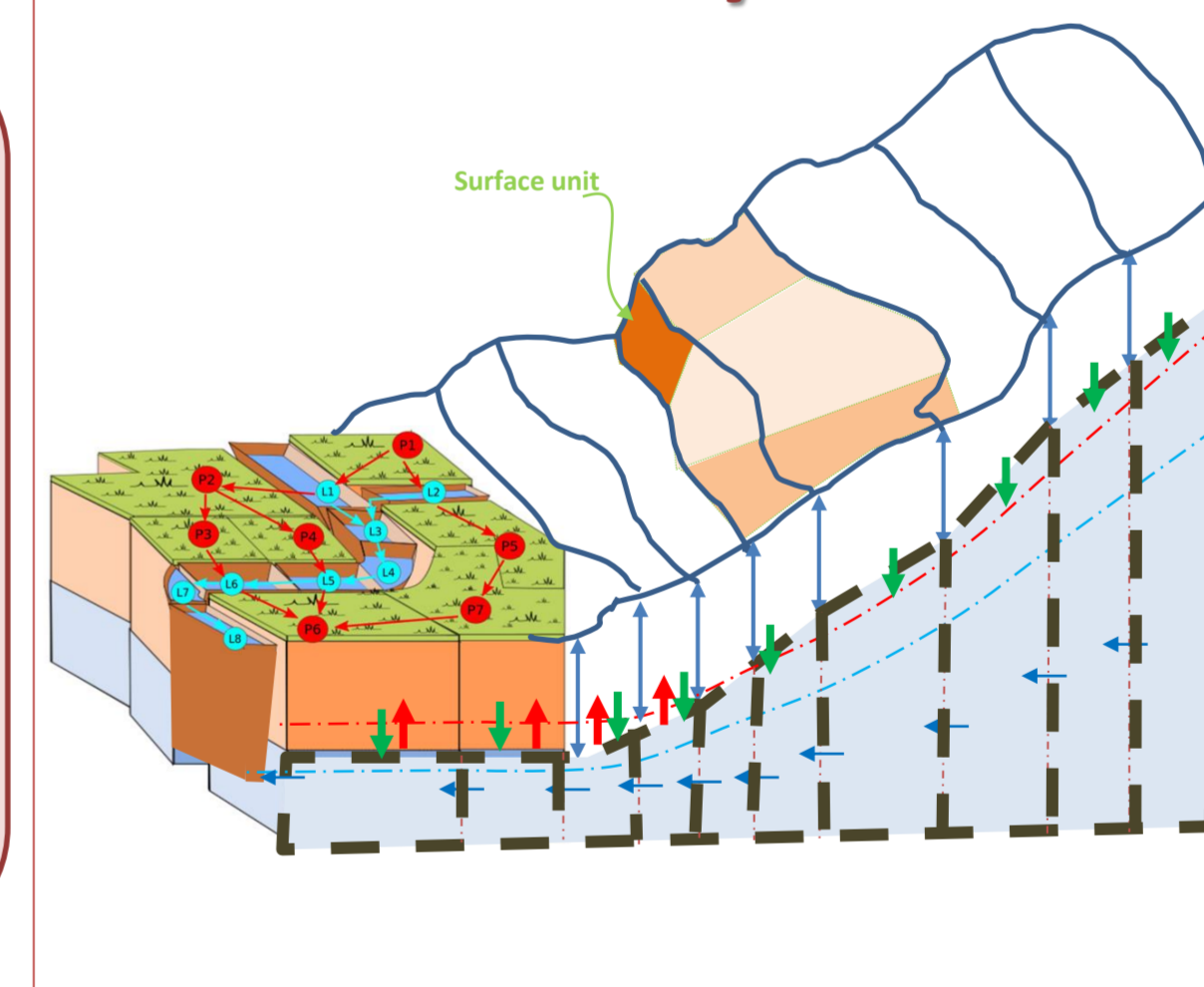
Consider the entire aquifer as a unique reservoir. Test different mixing schemes:  
- Random sampling  
- Preference to old water  
- Preference to young water  
- Variable preference with time.

### Semi-distributed approach



Consider different subdivisions of the aquifer. Test multiple criteria:  
- Topography (lowland, hillslope, plateau)  
- Soil occupations (forest, vineyards, pasture)  
- Agricultural practices (active substances, doses)

### Fully distributed approach

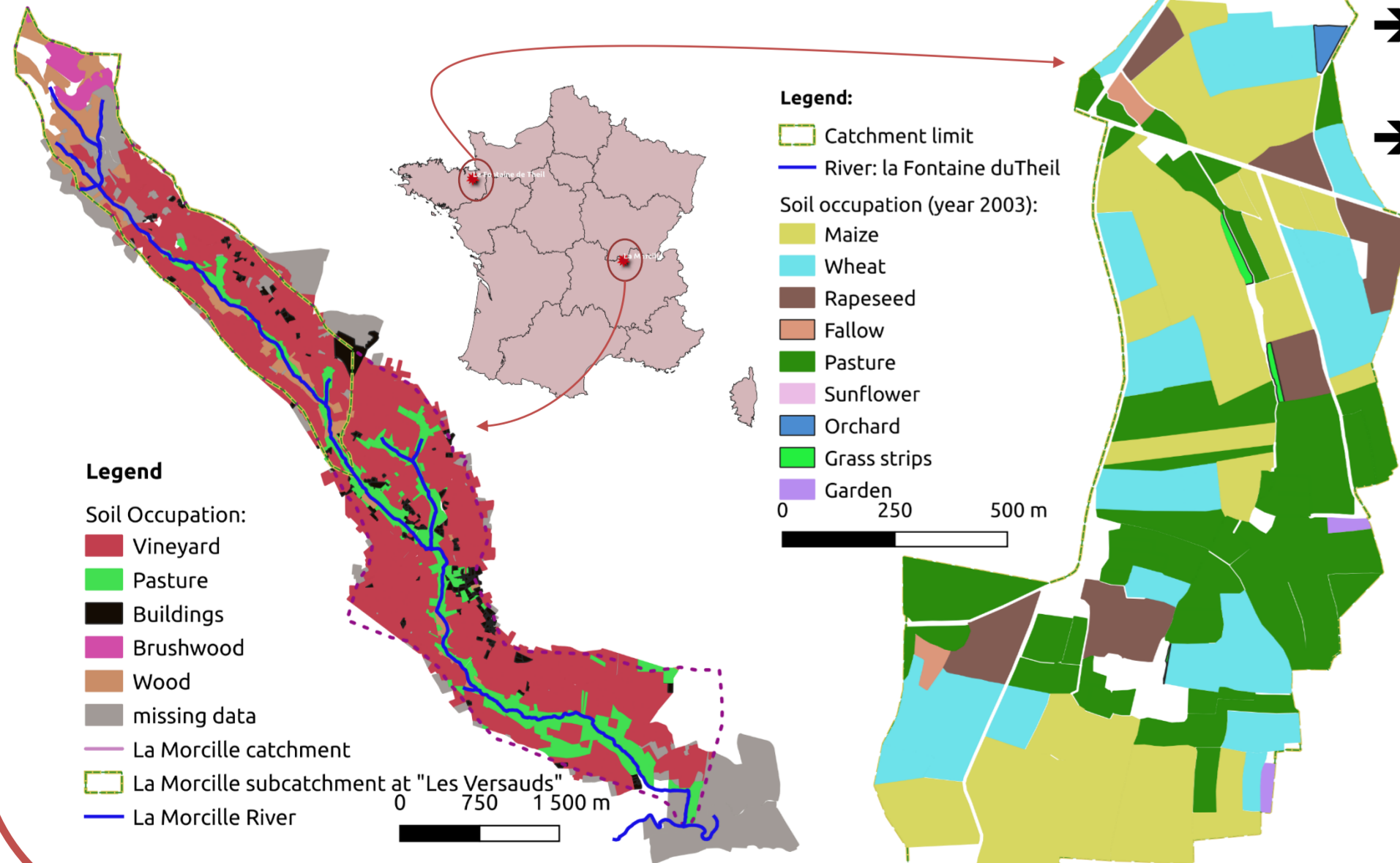


Consider a fully distributed aquifer. Test to compare the other scenarios in terms of:  
- Parametrization  
- Computation time  
- Model performance...

## Two catchments with contrasted pedo-agroclimatic contexts

La Morcille

La Fontaine de Theil



→ To assess the impact of different surface landscapes on water quality  
→ To simulate various active substances with different physico-chemical behaviors  
→ To test the model performance according to data availability

	La Morcille (Versauds)	La Fontaine du Theil
Surface	480 ha	128 ha
Geology	Granite	Schist
Soil occupation	Vineyard & forest	Polyculture
Topography	Steep slopes	Mild slopes
Dominant landscapes	Ditches	Hedges
Good description:	Soils	Agricultural practices

## Data requirements

Hydrology and groundwater data (discharge, water table variations)

Chemistry data (concentrations of chemical elements and nitrates to understand the functioning of the catchments)

Water age tracers data (ChloroFluoroCarbons) to constrain the residence time distributions

Pesticide data (concentrations of pesticides and their degradation products in surface and groundwater)

Available data

Data to acquire

## Novelty of the approach

Applying SAS to groundwater compartment only: Most of SAS function applications are at the watershed scale

Combining with a mechanistic representation for water fluxes, to better describe the groundwater dynamics in hard rock catchments

Coupling with a surface/subsurface model to better represent pesticide remobilization in the unsaturated zone

Modeling simultaneously pesticides and their degradation products: we want to develop a generic approach for any reactive substance

Using CFCS to constrain residence time distribution in SAS function applications: instead of isotopic data that need long monitoring

## References

- [1] Botter, G., Bertuzzo, E., Rinaldo, A., 2011. Catchment residence and travel time distributions: The master equation. *Geophysical Research Letters* 38. <https://doi.org/10.1029/2011GL047666>
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