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## Sensitivity Analysis on a green roof hydrological model

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## Context

Urban imperviousness is a major urban issue during rainfall events

## Solution → Green Roofs

- lower the peak flow rate in water system by 22% to 93%
- delay the peak flow by 0 to 30 min

## Green Roofs hydrologic modeling

- Rainfall data and real water content measured in a green roof of the CEREMA of Nancy

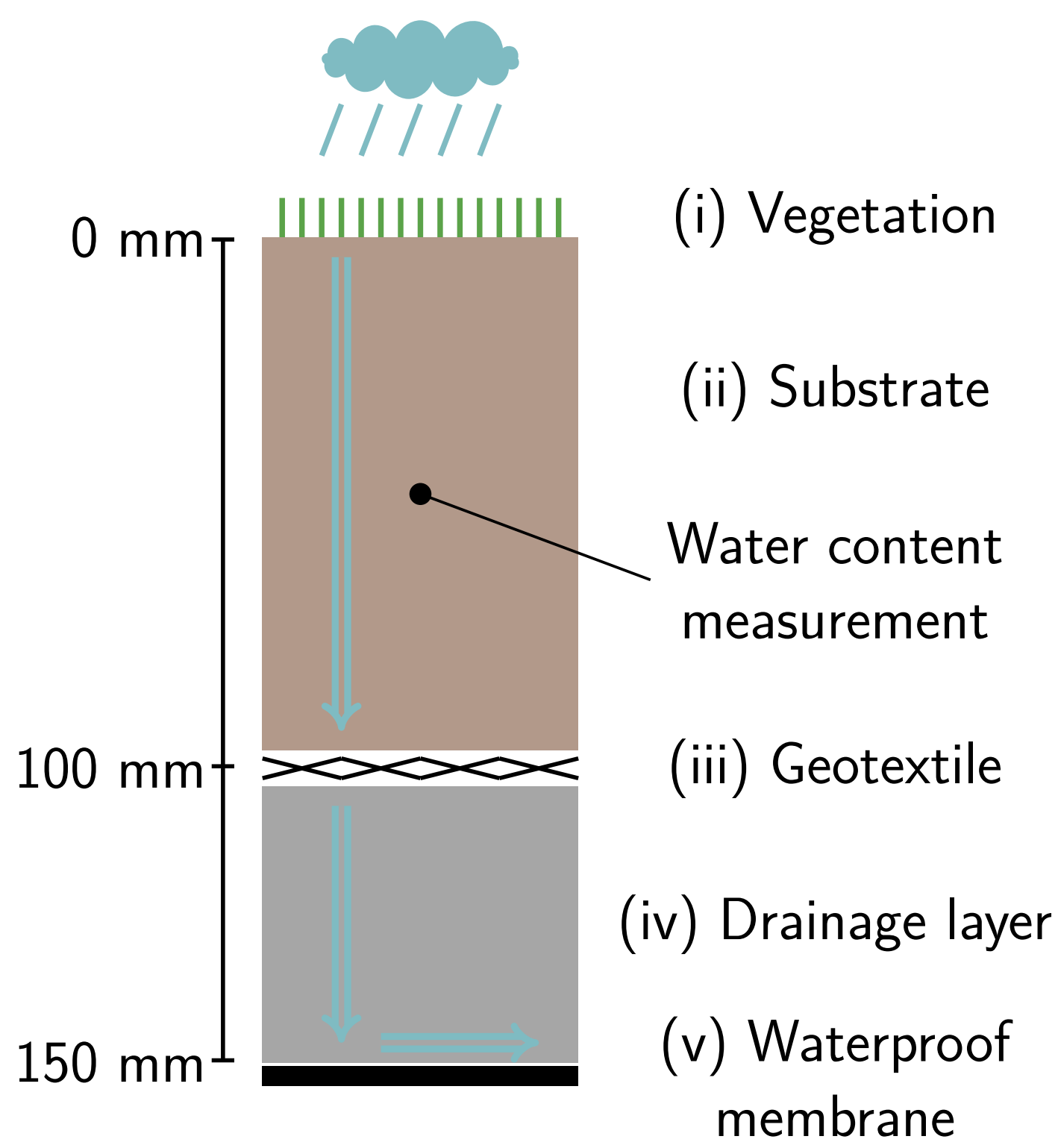


- Simulation of the water infiltration into the layers using Richards equation (1) implemented in Hydrus-1D software

$$\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial x} \left( K(\theta) \frac{\partial h}{\partial x} \right) - \frac{\partial K(\theta)}{\partial x} \quad (1)$$

combined with Van Genuchten model (2) and Mualem model (3)

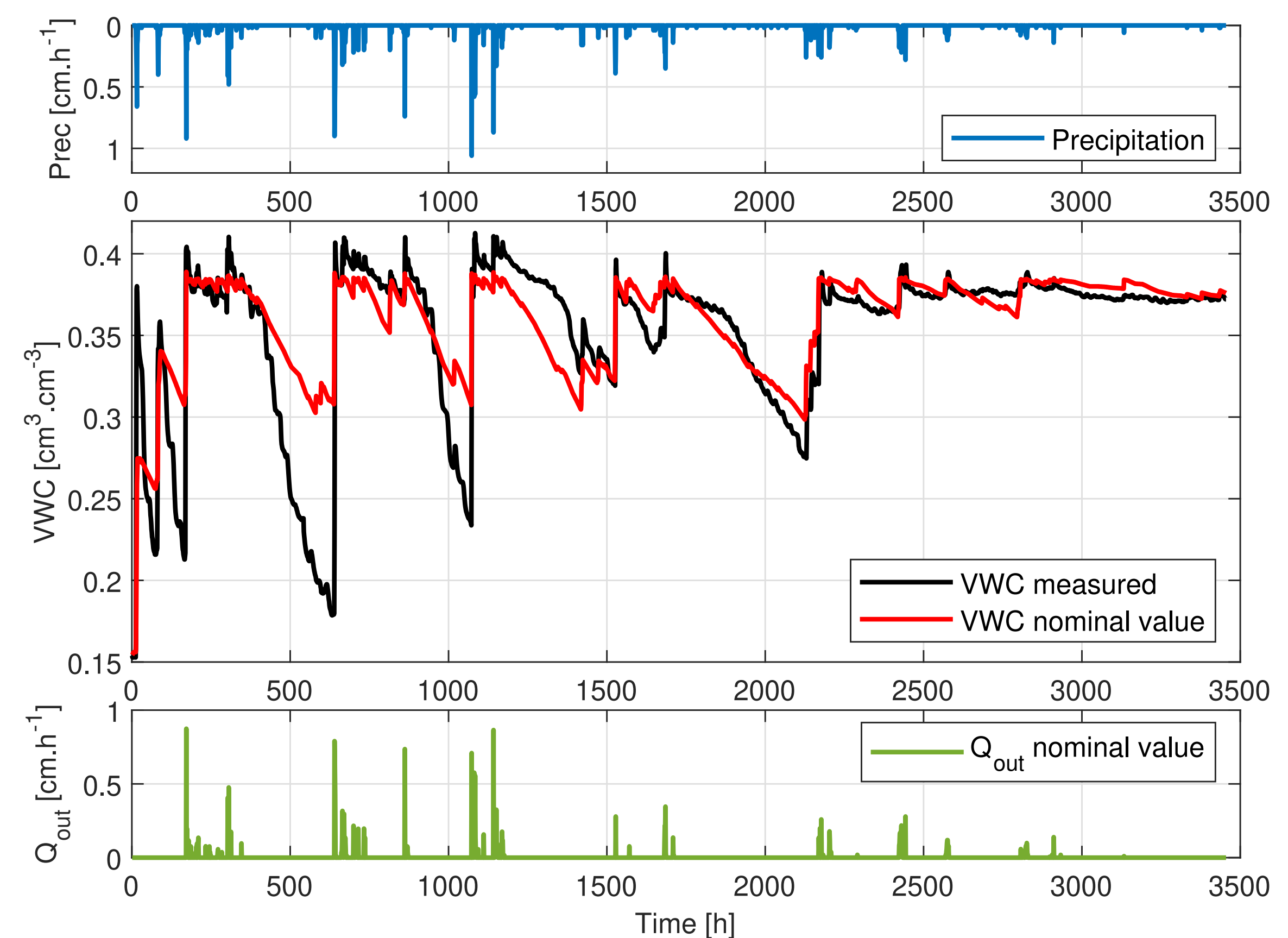
$$\theta(h) = \frac{\theta_s - \theta_r}{(1 + |\alpha h|^n)^m} - \theta_r \quad \text{with } m = 1 - \frac{1}{n} \quad (2) \quad K(S_e) = K_s S_e^l \left( 1 - (1 - S_e^{1/m})^m \right)^2 \quad \text{with } S_e(\theta) = \frac{\theta(h) - \theta_r}{\theta_s - \theta_r} \quad (3)$$



## Problem statement

- Input : Rainfall
- Output : Water content  $\theta(t)$  or  $VWC(t)$  in (ii)
- $k = 6$  uncertain parameters :  $\theta_s$ ,  $\theta_r$ ,  $K_s$ ,  $l$ ,  $n$  and  $\alpha$

Parameters	Unit	(ii) Substrate		(iv) Drainage	
		Inf	Sup	Inf	Sup
$\theta_r$	$\text{m}^3 \text{m}^{-3}$	0.072	0.088	0.054	0.066
$\theta_s$	$\text{m}^3 \text{m}^{-3}$	0.387	0.473	0.27	0.33
$\alpha$	$\text{m}^{-1}$	5.85	7.15	4.5	5.5
$n$	-	1.422	1.738	1.35	1.65
$K_s$	$10^{-3} \text{ms}^{-1}$	1.95	2.38	3.25	3.972
$l$	-	2.583	3.157	0.09	0.11



## GSA method

## Results on Green Roofs

Method based on PCE :

$$Y(t) = \mathcal{G}(X, t) = \sum_{j=0}^{+\infty} a_j(t) \psi_j(X_1, \dots, X_k) \quad (4)$$

Method applied at each time instant :

1. Define the distribution of uncertain parameters to compose  $\psi_j$   
Uniform distribution → Legendre Polynomials
2. Define  $p$ , the maximum development order of  $\psi_j$
3. Estimate the PC coefficients  $a_j(t)$  by solving a least square problem
4. Estimate sensitivity index (SI) with :

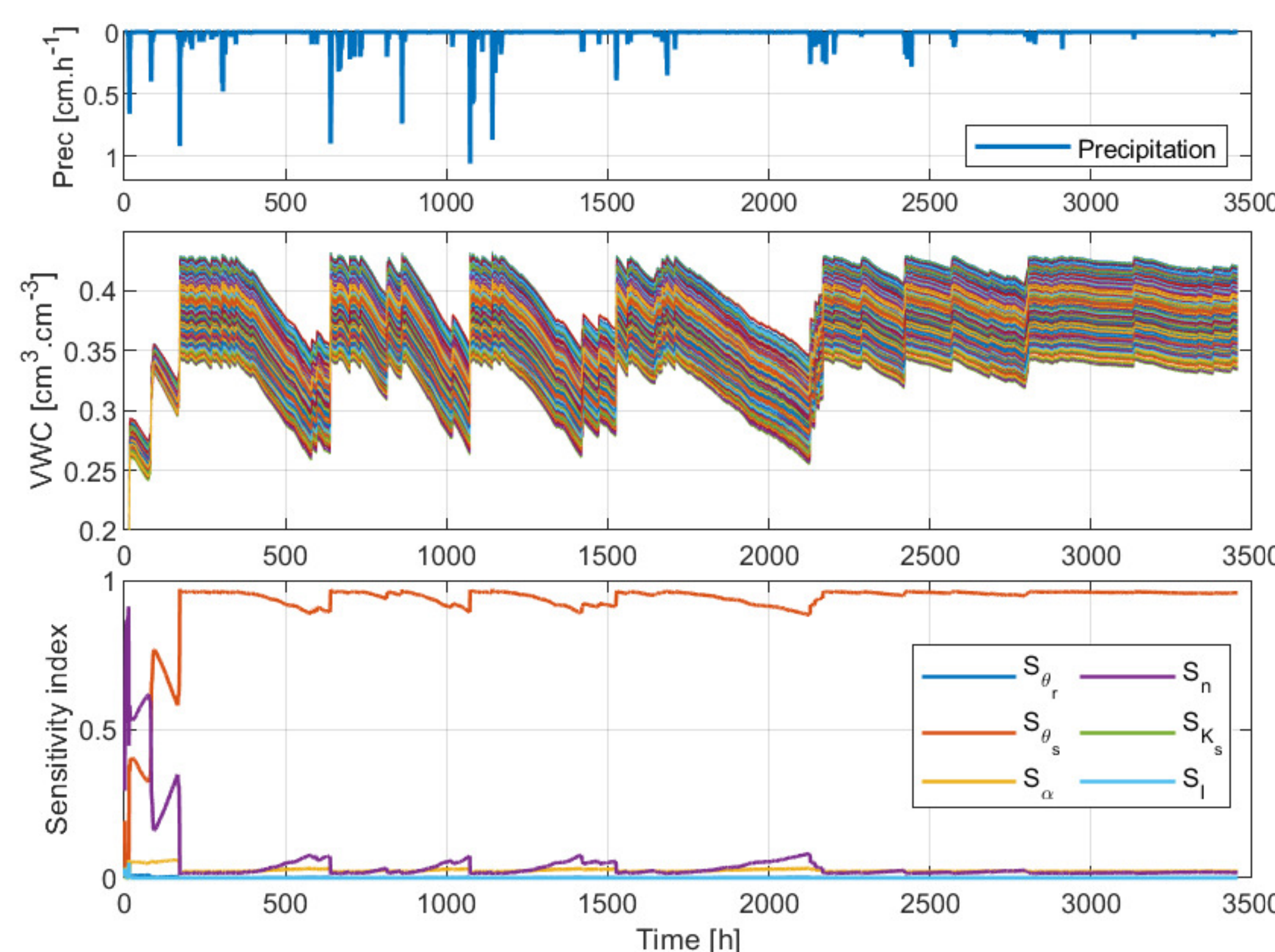
$$\text{First order SI : } S_i(t) \approx \frac{\sum_{j \in \mathcal{I}_i} a_j^2(t) E[\psi_j^2(X_i)]}{\text{var}[Y(t)]} \quad (5)$$

where  $\mathcal{I}_i$  is polynomial index of  $\psi_j$  which depends only on  $X_i$ 

$$\text{Total SI : } S_{T_i}(t) \approx \frac{\sum_{j \in \mathcal{I}_{\#i}} a_j^2(t) E[\psi_j^2(X_i)]}{\text{var}[Y(t)]} \quad (6)$$

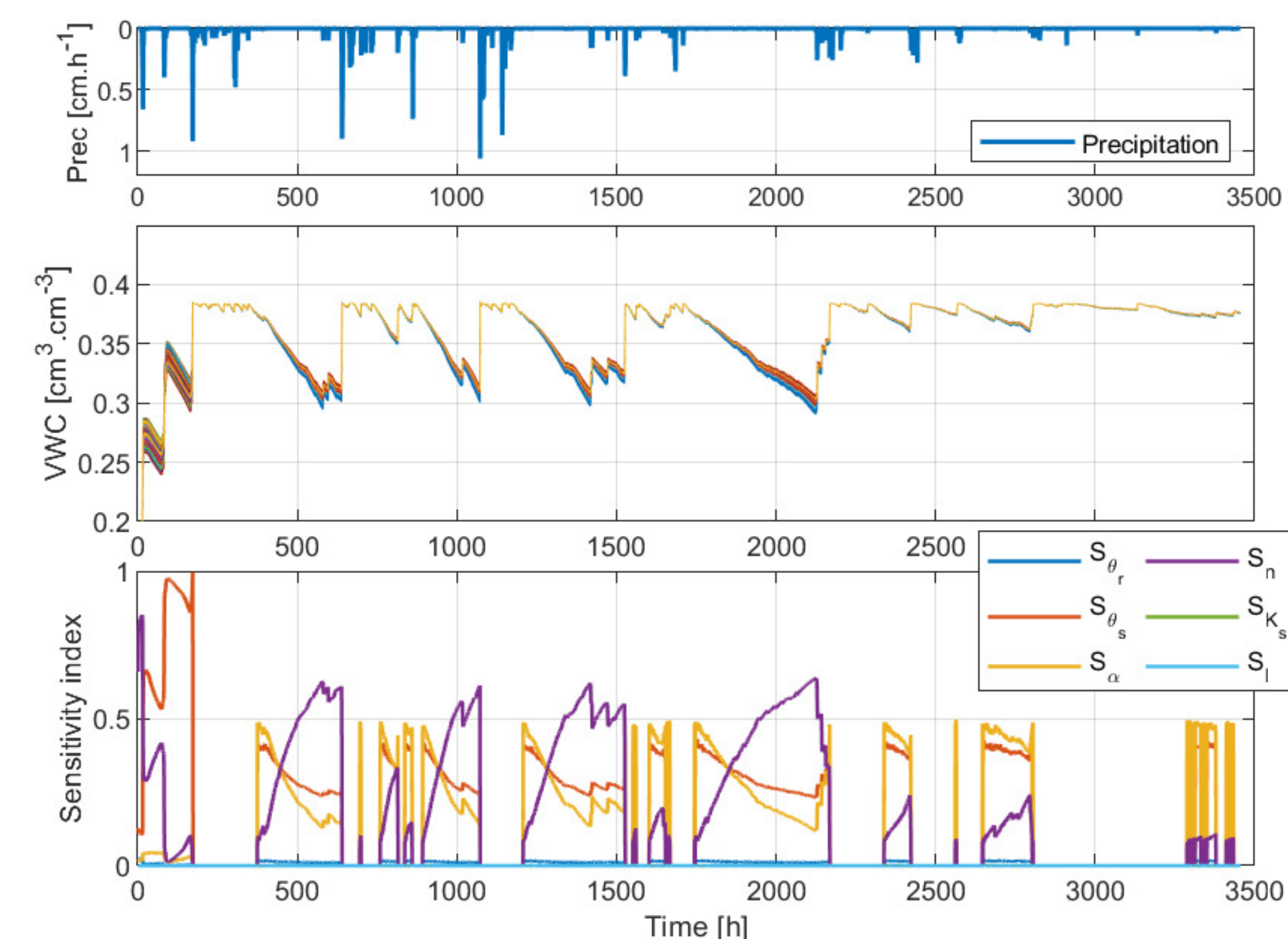
where  $\mathcal{I}_{\#i}$  is polynomial index of  $\psi_j$  which depends on  $X_i$  and all its interactions.

For the green roof model, 500 samples from Sobol sequence (QMC) to generate  $Y(t)$  and a development order  $p = 3$  to obtain indices is adapted

How vary the water content  $VWC(t)$  in the substrate when ...  
... substrate parameters vary ?

- Variations whatever  $VWC(t)$  evolution
- $S_i = S_{T_i}$  : no interaction between parameters
- 3 influential parameters : saturated water content  $\theta_s$ , pressure head fitting parameter  $\alpha$  and porosity distribution  $n$
- $S_{\theta_s}$  follows  $VWC(t)$  i.e.  $\nearrow$  when it rains
- $S_n$  inversely follows  $VWC(t)$  i.e.  $\searrow$  when it rains
- $S_\alpha$  varies slightly following  $VWC(t)$
- The other parameters are not influential

... drainage parameters vary ?



- No variation when  $VWC(t)$  is saturated
- As for the variation of substrate parameters, we have :
- $S_i = S_{T_i}$
  - Same 3 influential parameters and the other parameters uninfluential
  - Same dynamics for  $S_n$ ,  $S_{\theta_s}$  and  $S_\alpha$  but with more intensity

Parameter uncertainties of the different layers impact the water content with different intensity

## Conclusion and Prospect

- 3 influential parameters, saturated water content  $\theta_s$ , pressure head fitting parameter  $\alpha$  and porosity  $n$  and different influences depending on the layer
- Prospects : analyse the outflow and include meteorological uncertainties

## References

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