



HAL
open science

Sensitivity Analysis on a green roof hydrological model

Axelle Hego, Floriane Collin, Hugues Garnier, Rémy Claverie

► **To cite this version:**

Axelle Hego, Floriane Collin, Hugues Garnier, Rémy Claverie. Sensitivity Analysis on a green roof hydrological model. MascotNum Annual Conference, Apr 2021, Aussois, France. hal-03632462

HAL Id: hal-03632462

<https://hal.science/hal-03632462v1>

Submitted on 6 Apr 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Axelle HEGO¹, Floriane COLLIN¹, Hugues GARNIER¹, Rémy CLAVERIE²¹Université de Lorraine, CRAN, CNRS UMR 7039, ²Cerema Est, Team research group, F-54510, Tomblaine, France

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

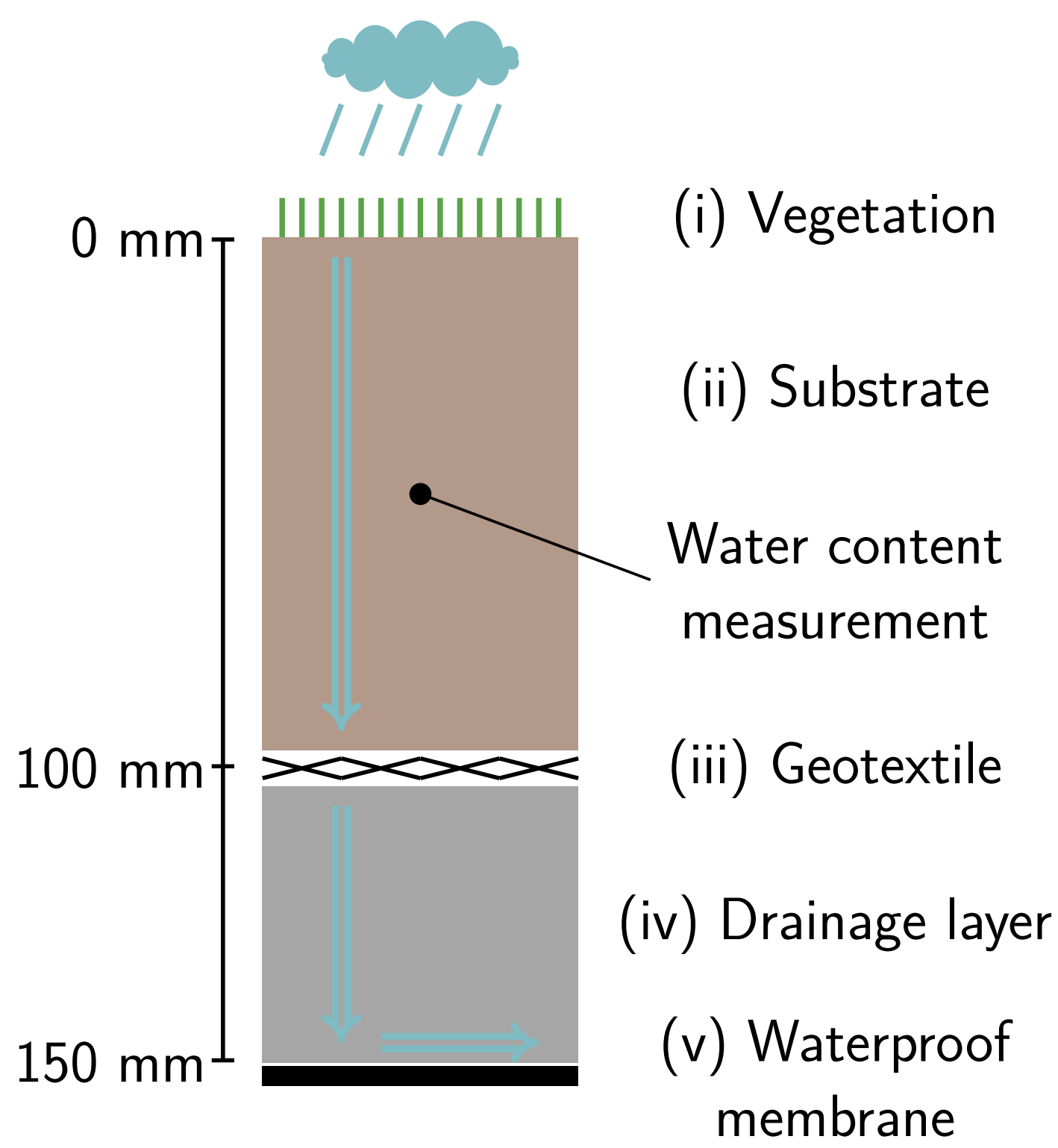


- Simulation of the water infiltration into the layers using Richards equation (1) implemented in Hydrus-1D software

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

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

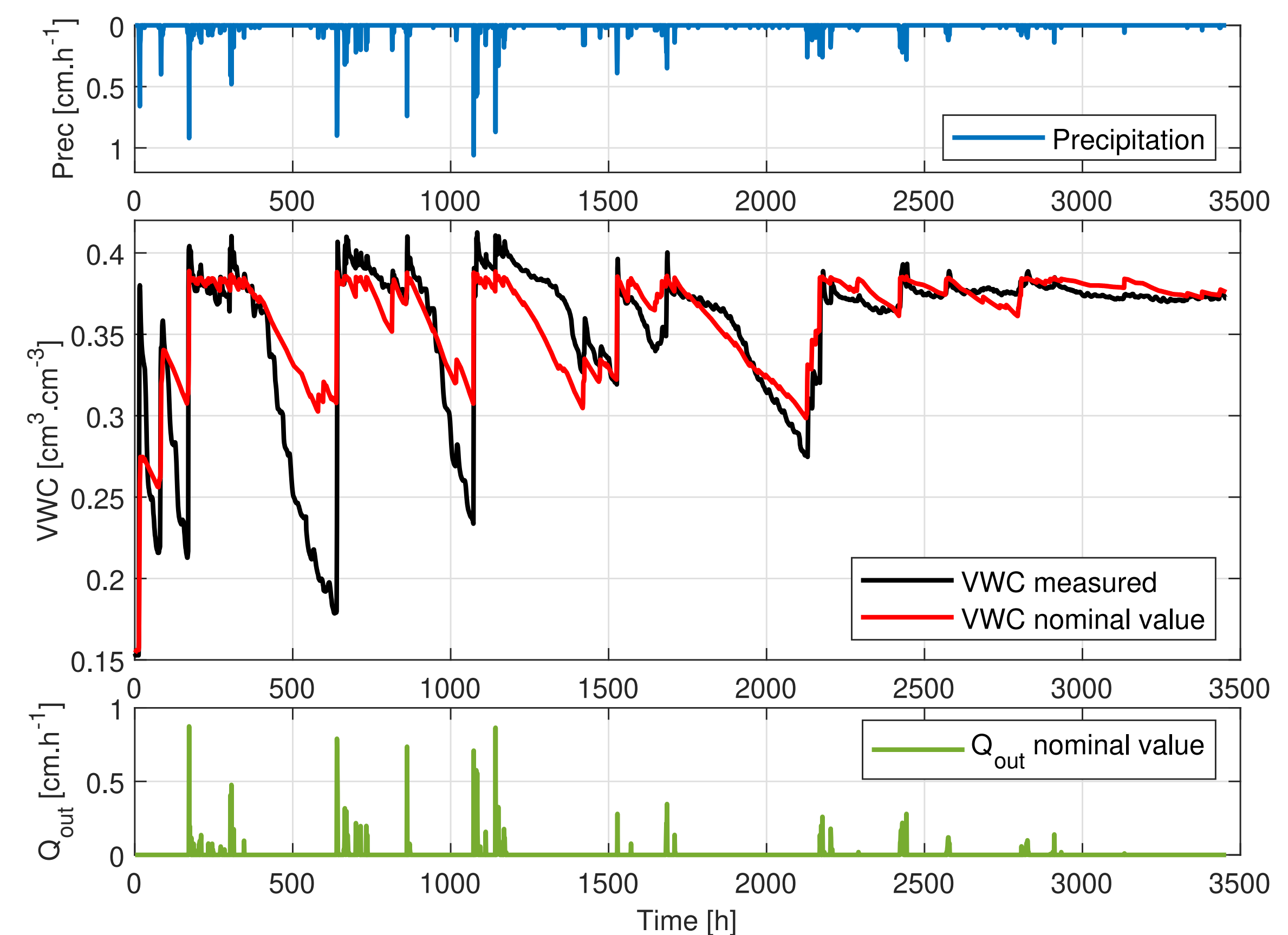
$$\theta(h) = \frac{\theta_s - \theta_r}{(1 + |\alpha h|^n)^m} - \theta_r \quad \text{with } m = 1 - \frac{1}{n} \quad (2) \quad K(S_e) = K_s S_e^l \left(1 - (1 - S_e^{1/m})^m \right)^2 \quad \text{with } S_e(\theta) = \frac{\theta(h) - \theta_r}{\theta_s - \theta_r} \quad (3)$$



Problem statement

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

Parameters	Unit	(ii) Substrate		(iv) Drainage	
		Inf	Sup	Inf	Sup
θ_r	$\text{m}^3 \text{m}^{-3}$	0.072	0.088	0.054	0.066
θ_s	$\text{m}^3 \text{m}^{-3}$	0.387	0.473	0.27	0.33
α	m^{-1}	5.85	7.15	4.5	5.5
n	-	1.422	1.738	1.35	1.65
K_s	10^{-3}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 ψ_j
Uniform distribution → Legendre Polynomials
2. Define p , the maximum development order of ψ_j
3. Estimate the PC coefficients $a_j(t)$ by solving a least square problem
4. Estimate sensitivity index (SI) with :

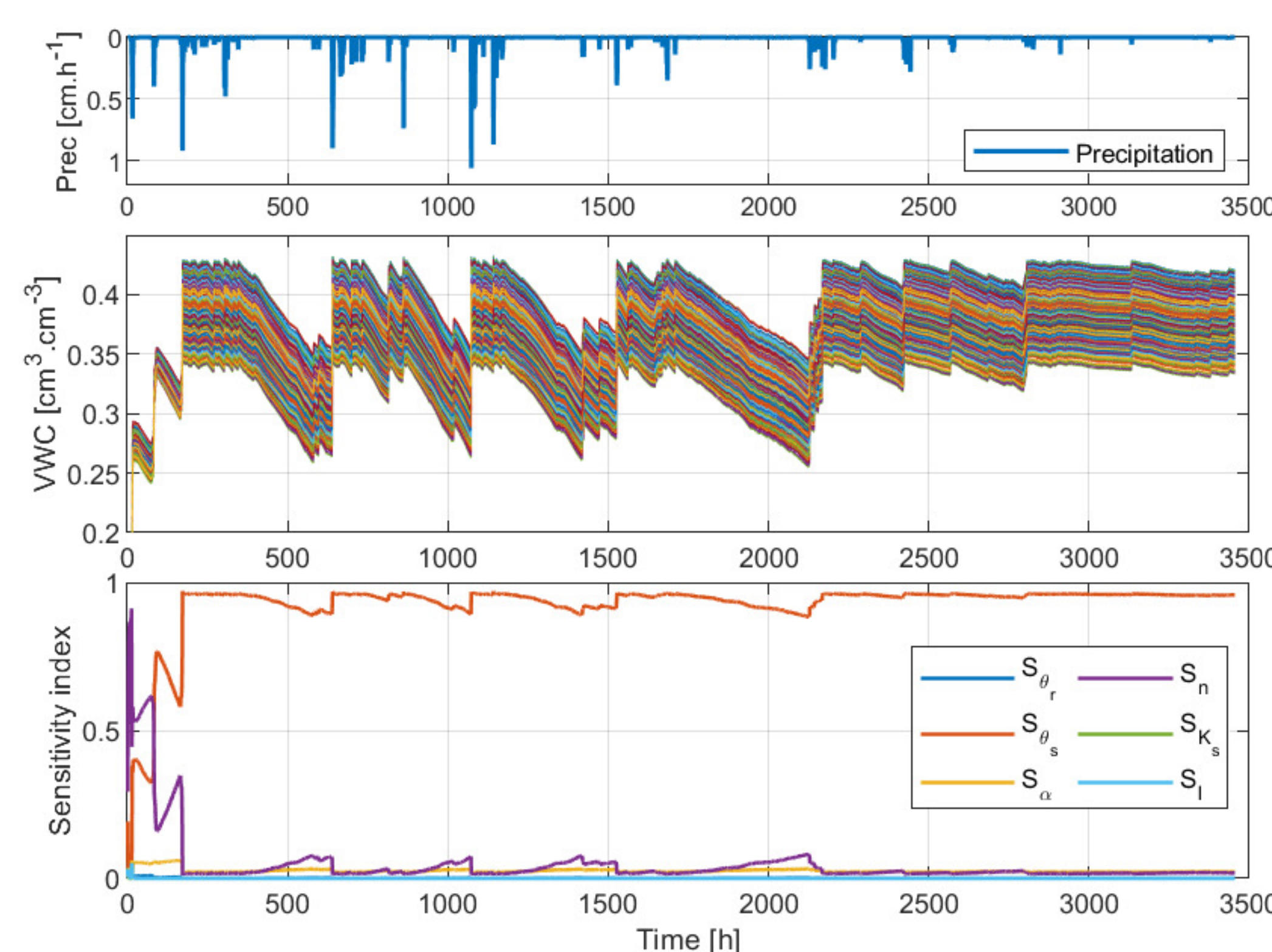
$$\text{First order SI : } S_i(t) \approx \frac{\sum_{j \in \mathcal{I}_i} a_j^2(t) E[\psi_j^2(X_i)]}{\text{var}[Y(t)]} \quad (5)$$

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

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

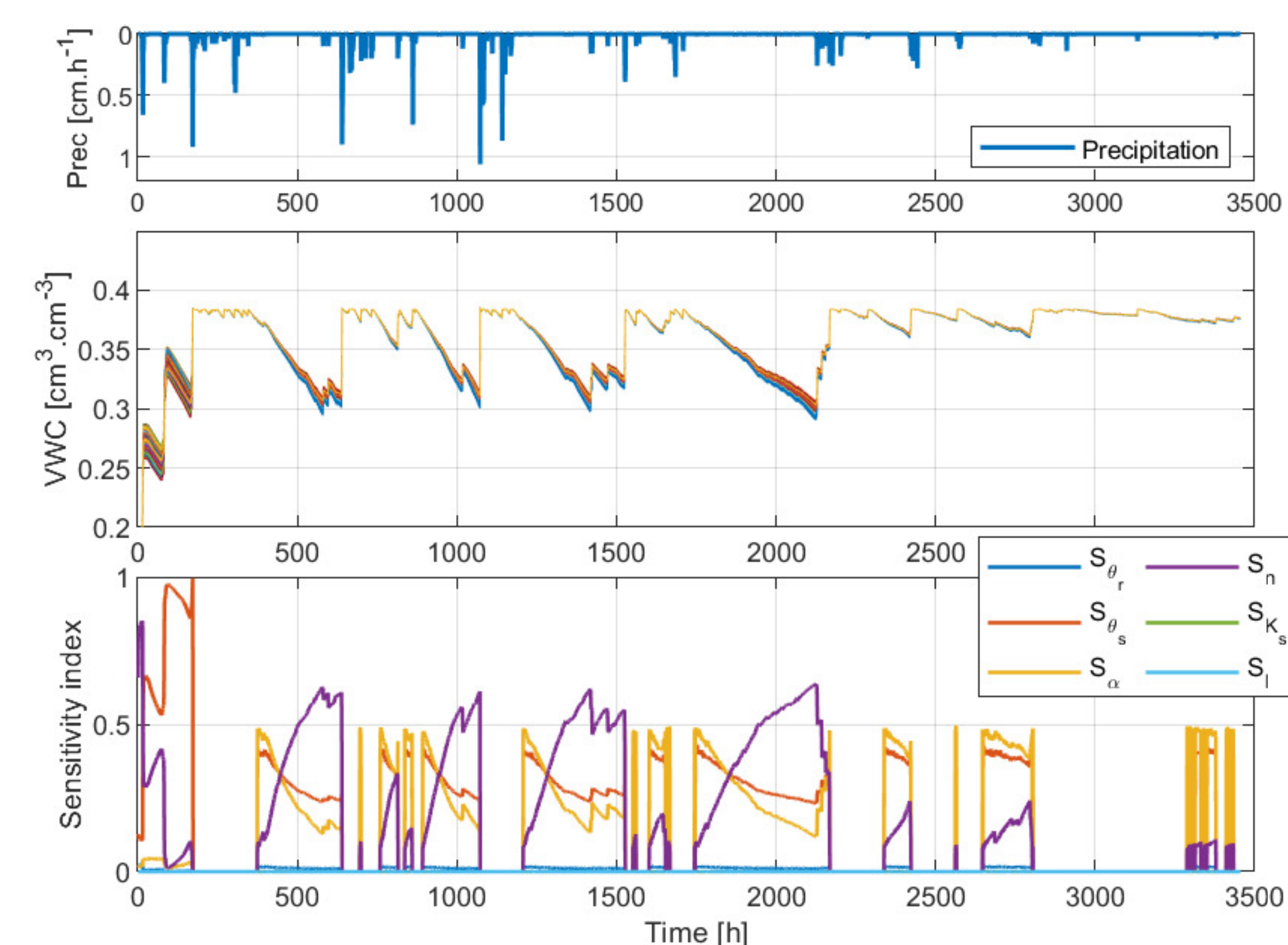
where $\mathcal{I}_{\#i}$ is polynomial index of ψ_j which depends on X_i and all its interactions.

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 θ_s , pressure head fitting parameter α and porosity distribution n
- S_{θ_s} follows $VWC(t)$ i.e. \nearrow when it rains
- S_n inversely follows $VWC(t)$ i.e. \searrow when it rains
- S_α 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_{θ_s} and S_α 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 θ_s , pressure head fitting parameter α and porosity n and different influences depending on the layer
- Prospects : analyse the outflow and include meteorological uncertainties

References

- Sandoval E.H. and Collin F. and Basset M. *Sensitivity study of dynamic systems using polynomial chaos*, Reliability Engineering & System Safety, 104 : 15–100, 2012.
- Bouzouidja R. et al. *Green roof aging : Quantifying the impact of substrate evolution on hydraulic performances at the lab-scale*, Journal of Hydrology, 564 : 416–423, 2018.