

How do the soil, the vegetation and the weather affect the water content of a green roof ?

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Figure 1 – Green roof located in Tomblaine (France)

Context

Urban imperviousness is a major urban issue during rainfall

Solution → Green Roofs

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

Collaboration

Cerema: Green Roofs experts

CRAN: Model Analysis skills



Collaboration between Cerema and CRAN for a better understanding of the GR behavior

Green Roofs hydrological modeling

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

- Simulation of the water infiltration into the layers using Hydrus-1D[®] software where these equations are implemented:

$$\underbrace{\frac{\partial \theta(h)}{\partial t}}_{\text{water content}} = \underbrace{\frac{\partial}{\partial x} K(\theta) \left[\frac{\partial h}{\partial x} - 1 \right]}_{\text{water infiltration in the soil (1)}} - \underbrace{S(h)}_{\text{plant effect (2)}}$$

(1) Richards equation which describes water infiltration in the soil

(2) combination of Feddes function and Penman-Monteith equation which describe plants effect

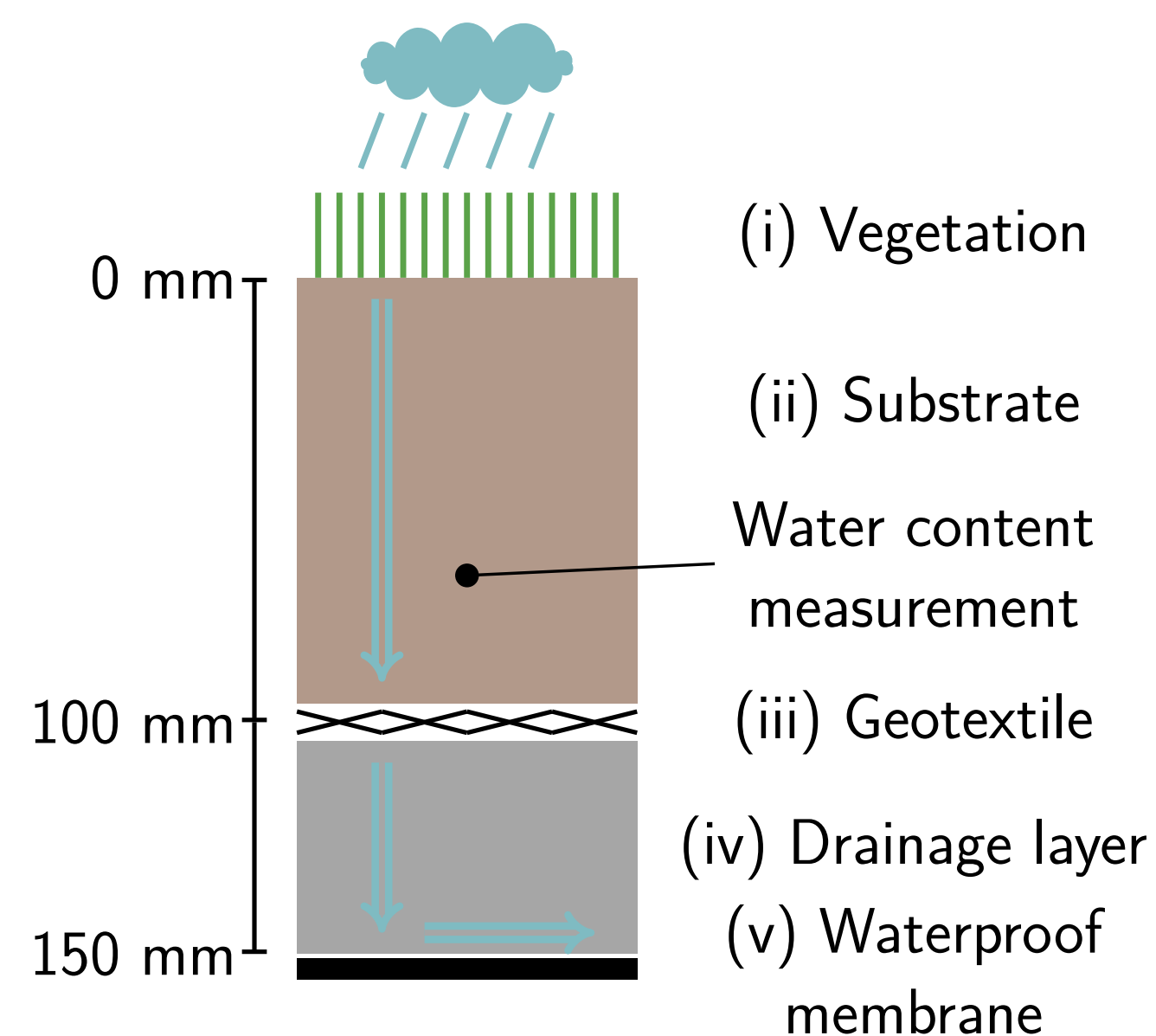


Figure 2 – Profile view of a green roof

Problem statement

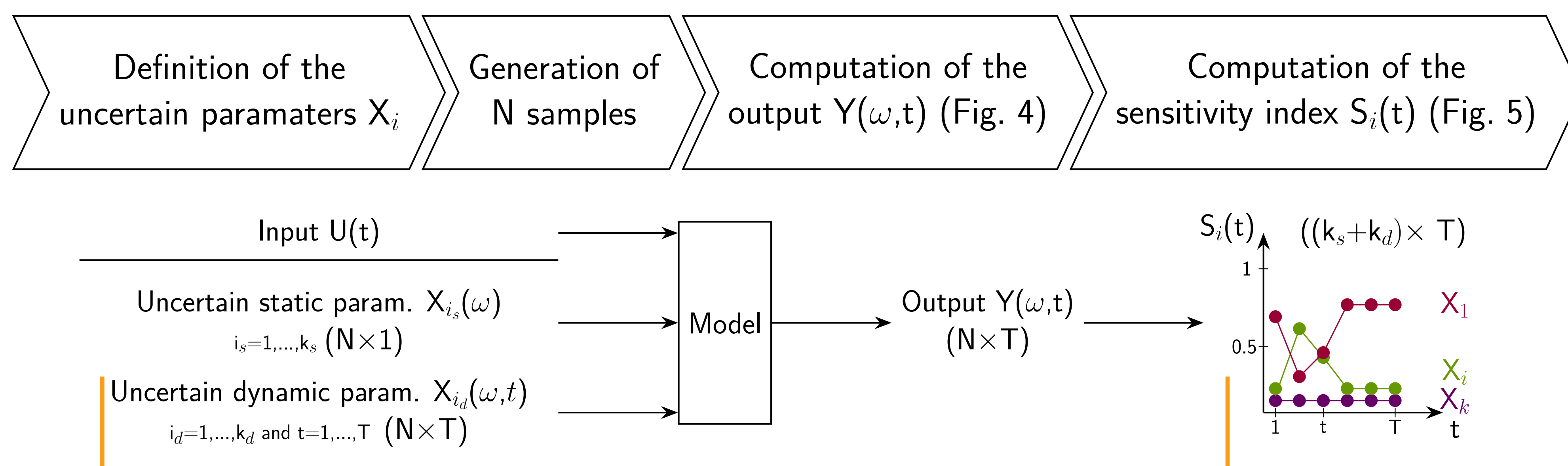
- Input: Rainfall;
- Output: Volumetric water content $\theta(t)$ or VWC in the substrate (ii) (Fig. 2);
- 6 soil parameters: θ_s , θ_r , K_s , l , n and α ;
- 5 meteorological variables: temperatures T_{max} , T_{min} , radiation R_n , air moisture, wind speed;
- 4 vegetation parameters: crop height, LAI, albedo and root depth.

→ 5 parameters are considered **uncertain**: θ_s , n , α , LAI and $R_n(t)$

What parameters affect the water content (model output) ?

Methods: Generation of uncertain dynamic input for GSA

Aim of Global Sensitivity Analysis (GSA) : Better understand the model behavior



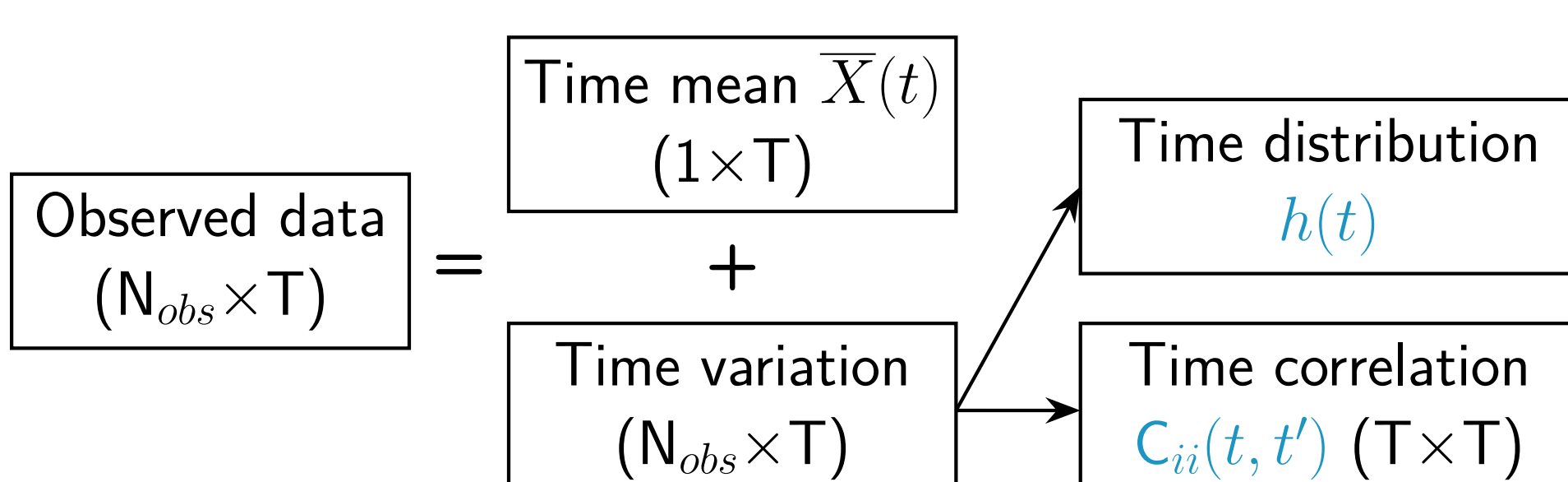
Challenge 1: How to generate dynamic input ?

- (1) Each dynamic param. can be defined as:

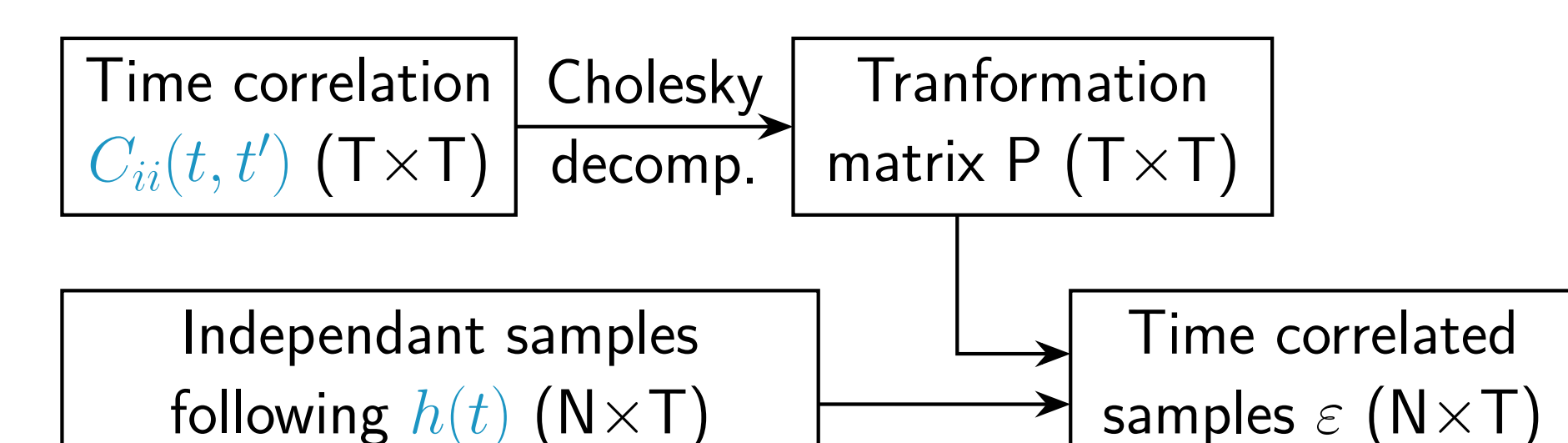
$$X_{id}(\omega, t) = \bar{X}(t) + \varepsilon(\omega, t)$$

with ω the randomness, $\bar{X}(t)$ the time mean and $\varepsilon(\omega, t)$ a stochastic variable defined by a correlation function $C_{ii}(t, t')$ and a distribution $h(t)$ for each instant.

- (2) Extraction of the statistical information from a data set:



- (3) Generation of dynamic param. using Iman and Conover procedure (1982):



- (4) Results: net radiation for a typical month of June in Fig. 3

Challenge 2: How to compute sensitivity indices ?

- For each instant, parameters are independant
- Computation of the indices for each instant
- Method: Sobol' indices estimated using samples permutation
- Results presented in Fig. 5

Conclusion and Prospect

- 2 samples of 5000 samples (LHS) generated and corresponding outputs computed
- Sensitivity indices are consistent with previous results (bootstrap in progress)

Prospects:

- How to generate uncertain dynamic input for non-stationary period ?
- Other estimator for sensitivity indices ?

References

- Goffart J., Mara T. and Wurtz E. *Generation of stochastic weather data for uncertainty and sensitivity analysis of a low-energy building*, Journal of Building Physics, 41(1): 41–57, 2017.
- Hégo A., Collin F., Garnier H. and Clavierie R. *Approaches for green roof dynamic model analysis using GSA*, IFAC-PapersOnLine, 54(7): 613–618, 2021.

Access to the poster

Results

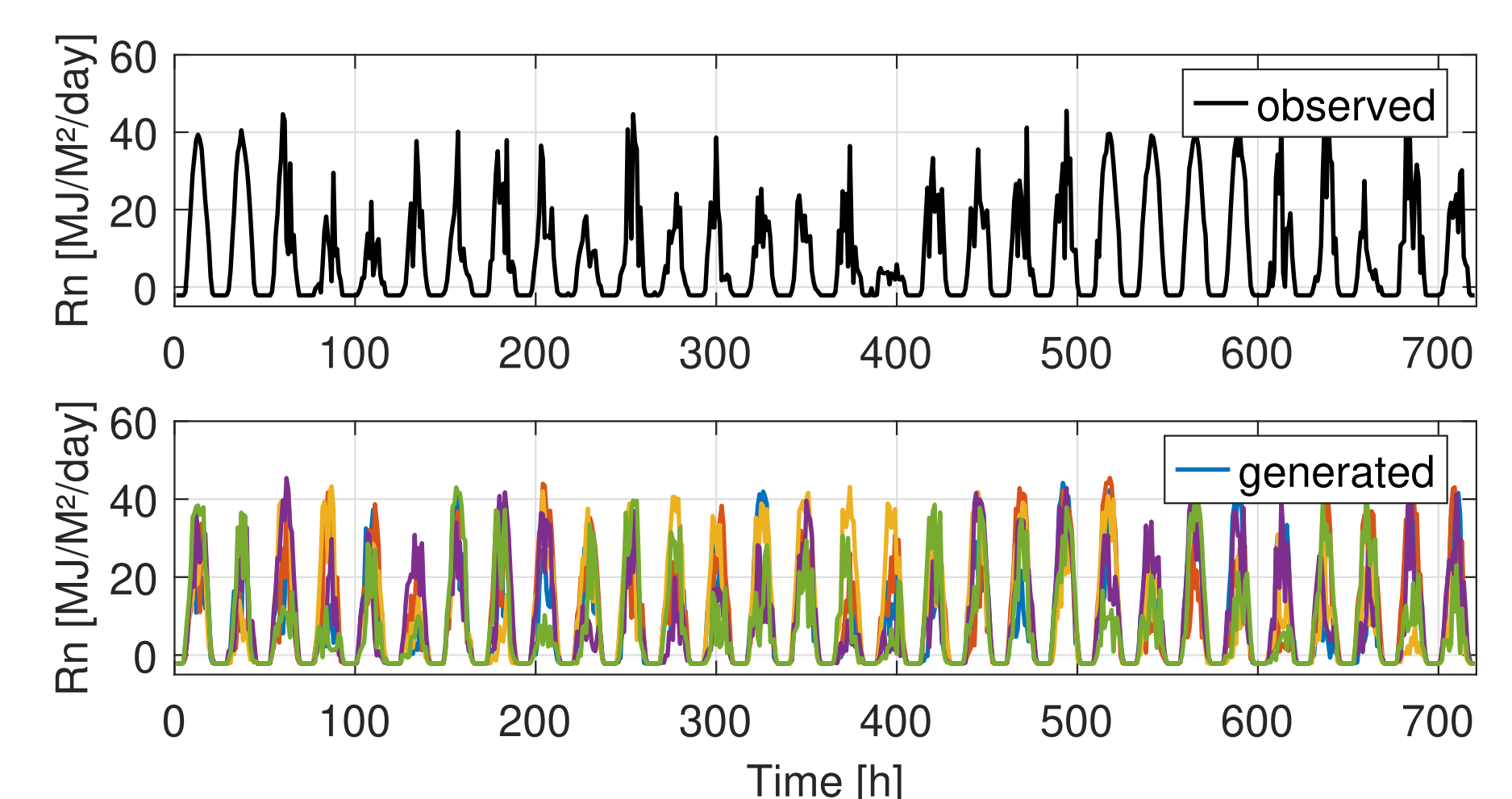


Figure 3 – Observed net radiation $R_n(t)$ of June 2020 and some generated samples.

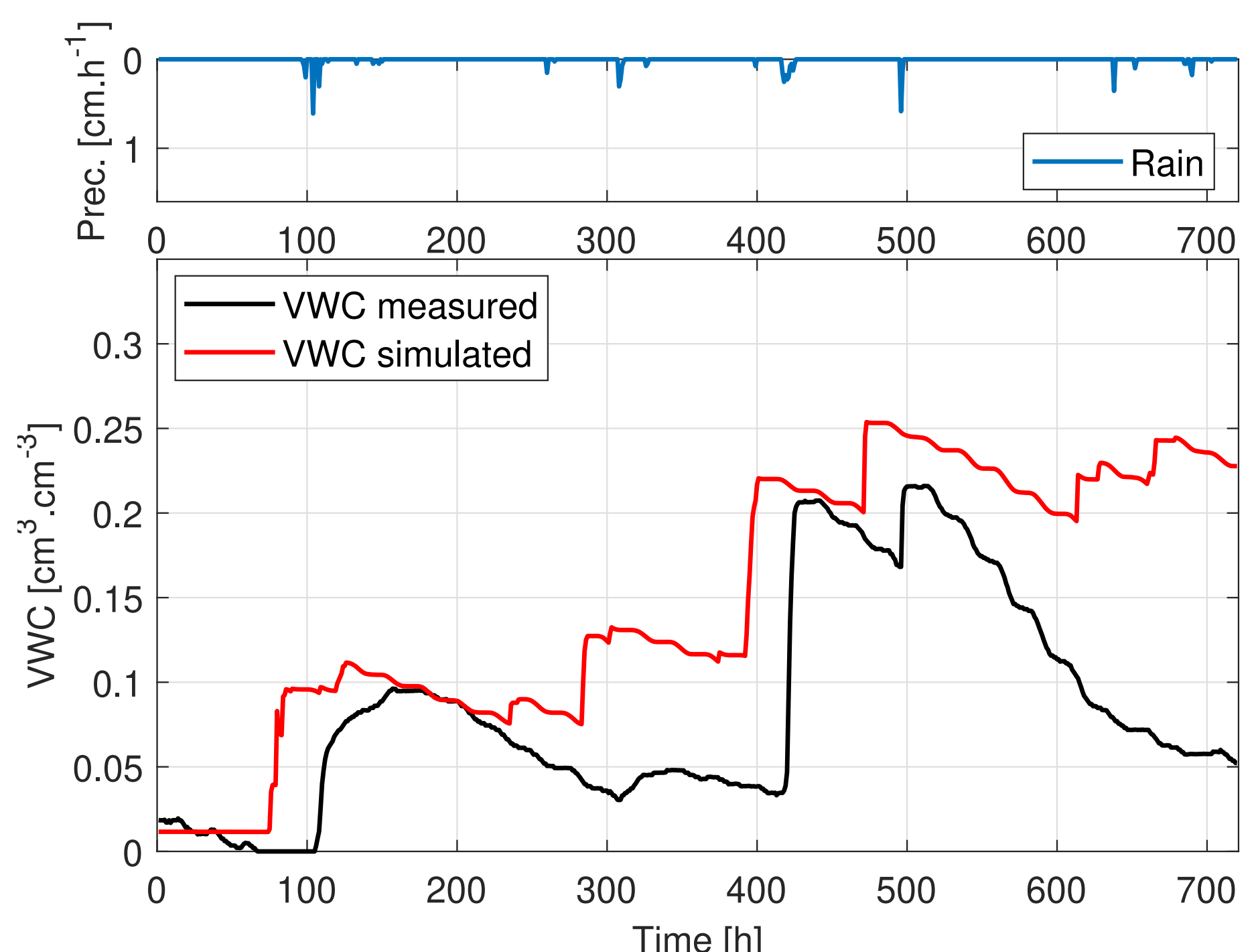


Figure 4 – Observed and simulated water content VWC and rainfall of June 2020

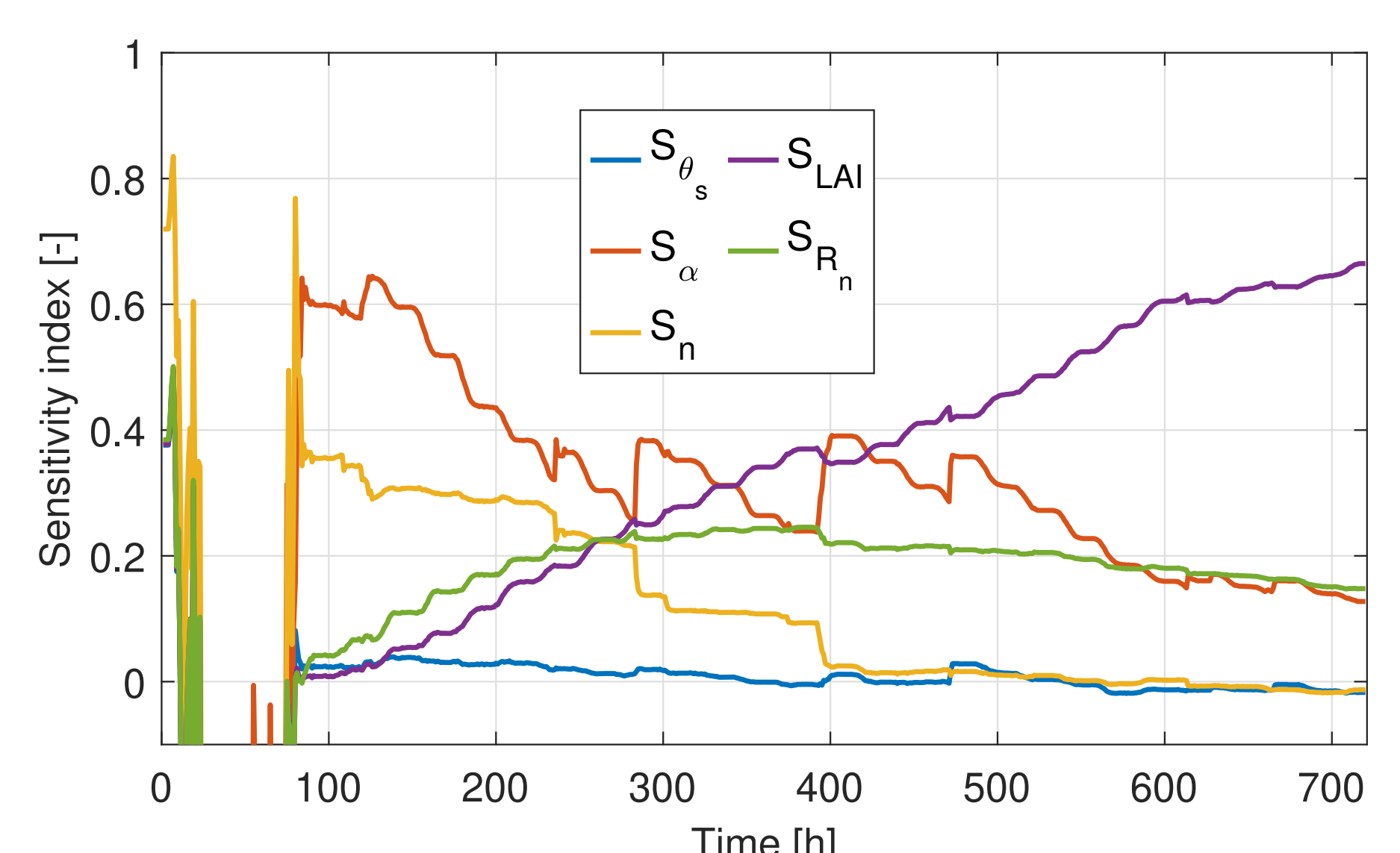


Figure 5 – First-order sensitivity indices computed using permutation method.