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

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:

\[
\frac{\partial h(t)}{\partial t} = \frac{\partial K(\theta)}{\partial x} \left[ \frac{\partial h(t)}{\partial x} - 1 \right] - S(h(t))
\]

(1) Richards equation which describes water infiltration in the soil
(2) combination of Feddes function and Penman-Monteith equation which describe plants effect

Problem statement

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

→ 5 parameters are considered uncertain: \( \theta_s, \alpha, K_s, K_i, R_n(t) \)

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

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<th>Definition of the</th>
<th>Generation of</th>
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<th>Computation of</th>
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<td>uncertain parameters ( x )</td>
<td>uncertain static param. ( x_i ) (N × 1)</td>
<td>output ( Y(x,t) ) (Fig. 4)</td>
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<tr>
<td>Input ( u(t) )</td>
<td>Uncertain dynamic param. ( x_i(t) ) (N × 1)</td>
<td>Model</td>
<td>Output ( Y(x,t) ) (N × T)</td>
</tr>
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</table>

Challenge 1: How to generate dynamic input ?

1. Each dynamic param. can be defined as:
   \[ x_i(t) = \bar{x}_i(t) + \epsilon_i(t) \]
   with \( \epsilon_i(t) \) the randomness, \( \bar{x}_i(t) \) the time mean and \( \epsilon_i(t) \) a stochastic variable defined by a correlation function \( C_{i,j}(t,t') \) and a distribution \( h(t) \) for each instant.

2. Extraction of the statistical information from a data set:
   \[ \text{Observed data} (N_{\text{obs}} \times T) \]
   \[ \begin{bmatrix} \text{Time mean} \bar{x}_i(t) \times (1 \times T) \\ \text{Time variation} (N_{\text{var}} \times T) \\ \text{Time correlation} C_{i,j}(t,t') (T \times T) \end{bmatrix} \]

   \[ \begin{bmatrix} \text{Time correlation} C_{i,j}(t,t') (T \times T) \\ \text{Cholesky decom.} \end{bmatrix} \]
   \[ \begin{bmatrix} \text{Transformation matrix} P (T \times T) \\ \text{Indepant samples following } h(t) (N \times T) \\ \text{Time correlated samples } \times (N \times T) \end{bmatrix} \]

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 independent
- Computation of the indices for each instant
- Method: Sobol’ indices estimated using samples permutation
- Results presented in Fig. 5

Results

- 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 ?

Conclusion and Prospect


References