Calibrating a hydrological model robustly to rain perturbations with stochastic surrogates

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Inria

Context

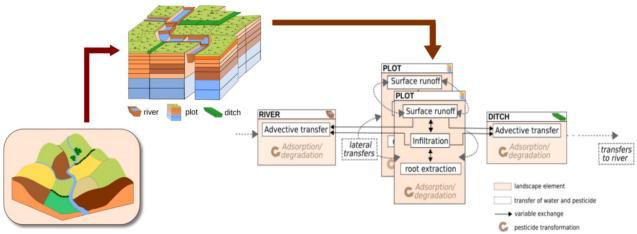
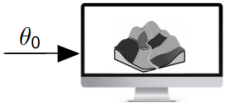


Figure: The PESHMELBA model, Rouzies, E., Lauvernet, C., Barachet, C., Morel, T., Branger, F., Braud, I., Carluer, N. (2019). From agricultural catchment to management scenarios: A modular tool to assess effects of landscape features on water and pesticide behavior. Science of The Total Environment, 671, 1144–1160. https://doi.org/10.1016/j.scitotenv.2019.03.060.

- water and pesticide transfer model
- spatially distributed
- many parameters to be precised
- a part of them cannot be measured directly
- $=>$ calibrate the parameters with terrain observations

Introduction



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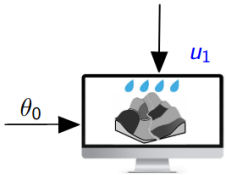

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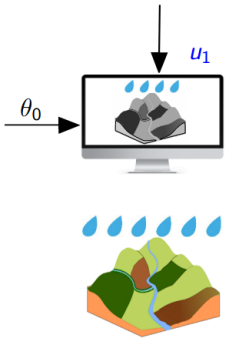

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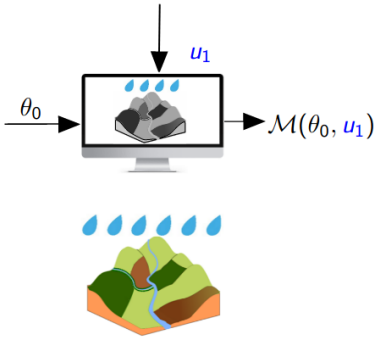

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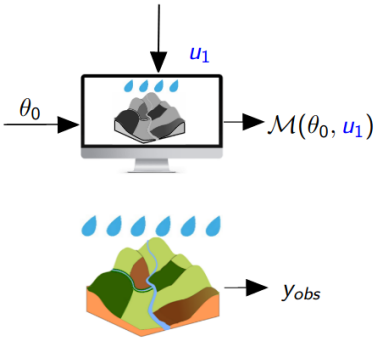

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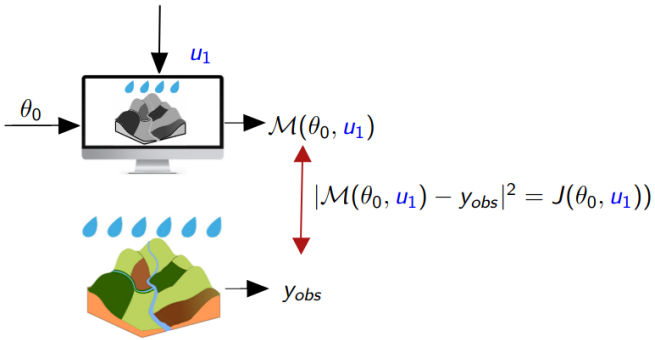

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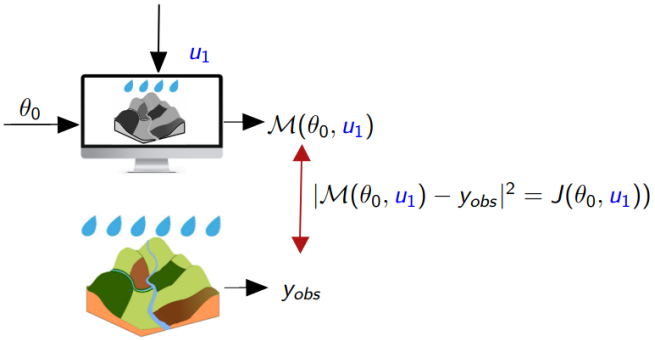

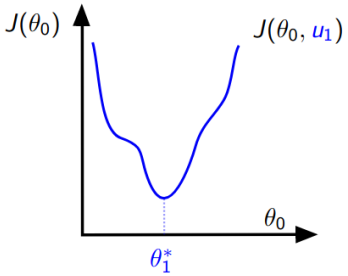

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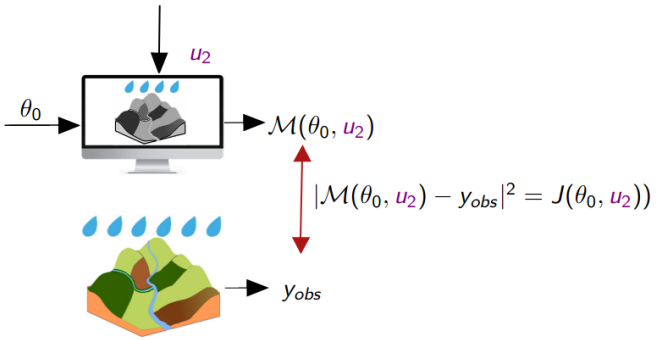

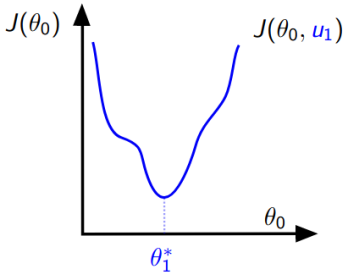

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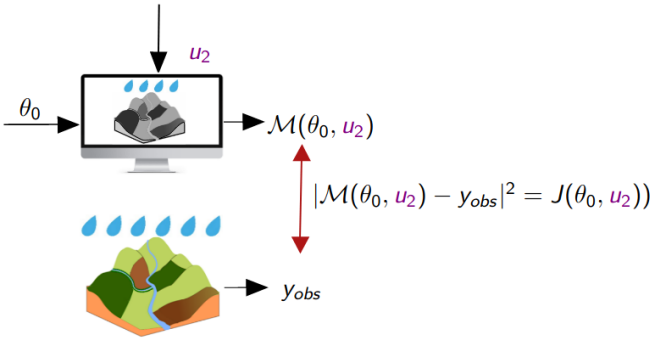

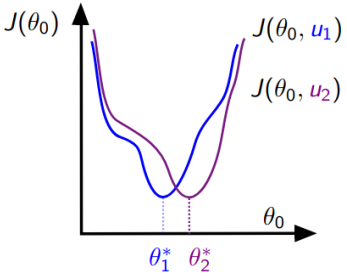

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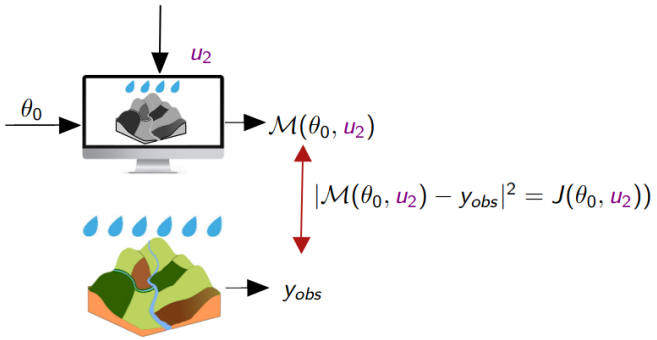

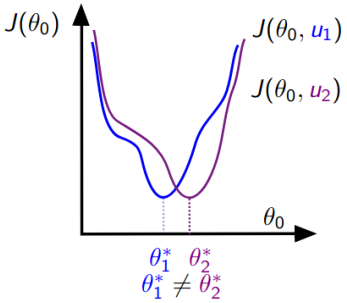

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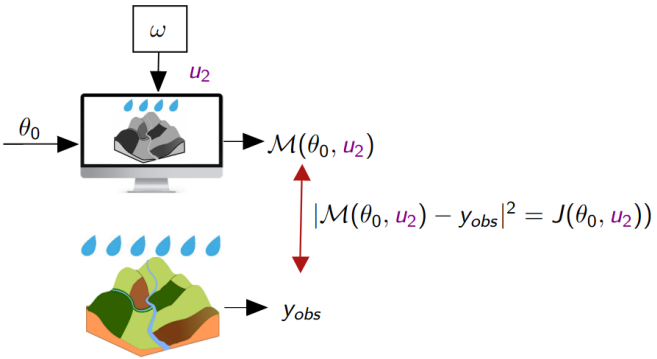

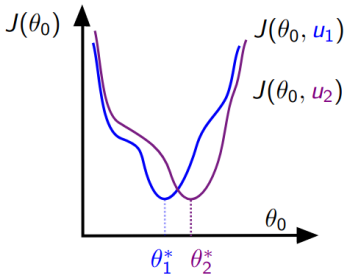

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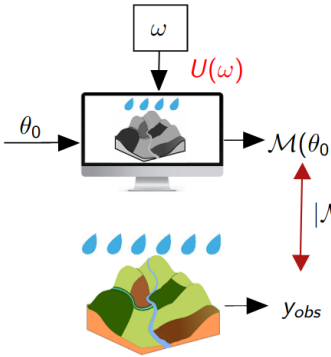

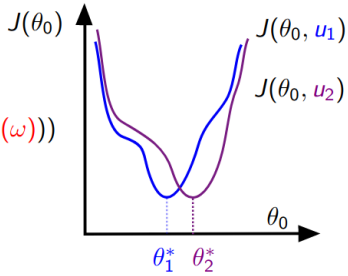

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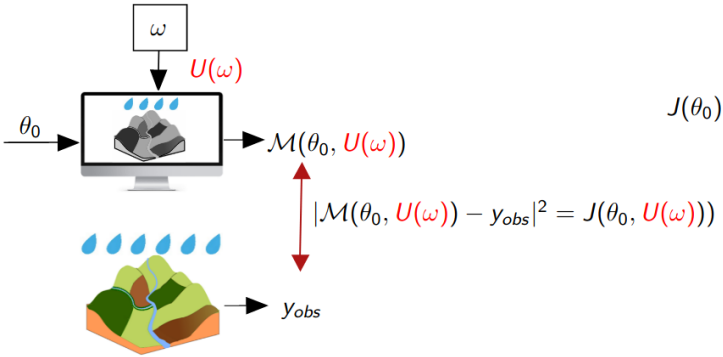

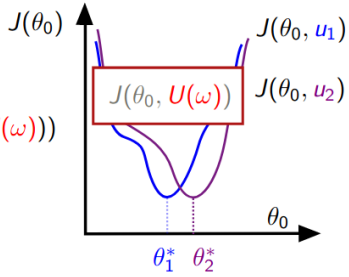

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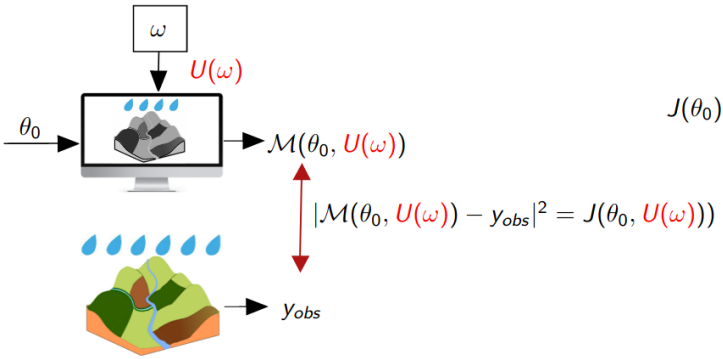
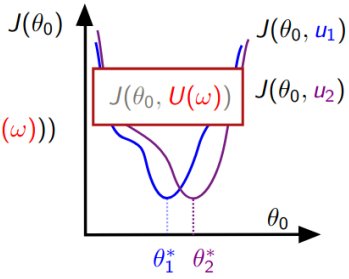
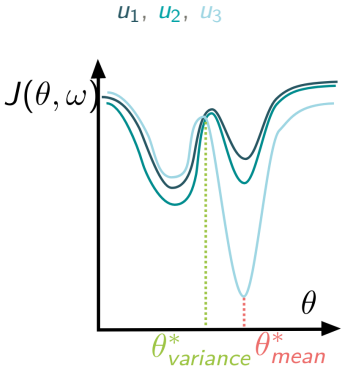




What does it mean to find a *robust* minimizer ?

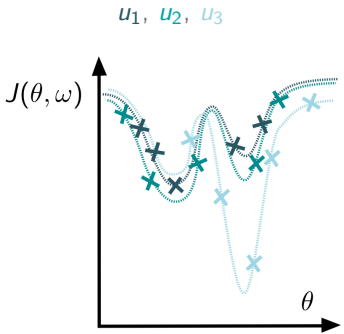
Methods: Robust estimators



1. $\boldsymbol{\theta}^*_{\mathbb{E}} = \underset{\boldsymbol{\theta}}{\text{argmin}} \mathbb{E}_U[J(\boldsymbol{\theta}, U)]$,
2. $\boldsymbol{\theta}^*_{\mathbb{V}ar} = \underset{\boldsymbol{\theta}}{\text{argmin}} \mathbb{V}ar_U[J(\boldsymbol{\theta}, U)]$,
3. Pareto of the two
4. ...

- What is the probability space of $U(\omega)$?

Methods: Robust estimators



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- How to estimate the robust parameters from a limited number of model simulations?

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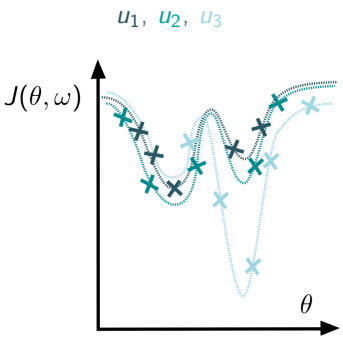

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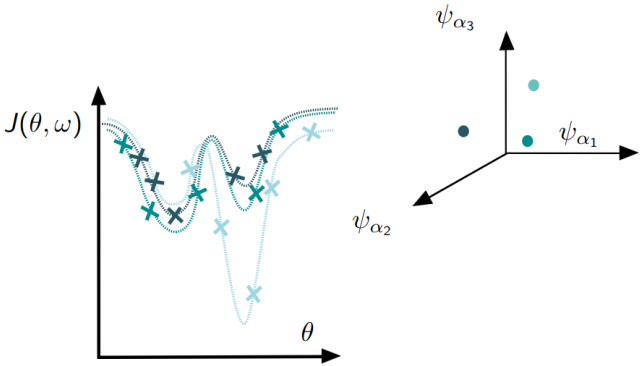
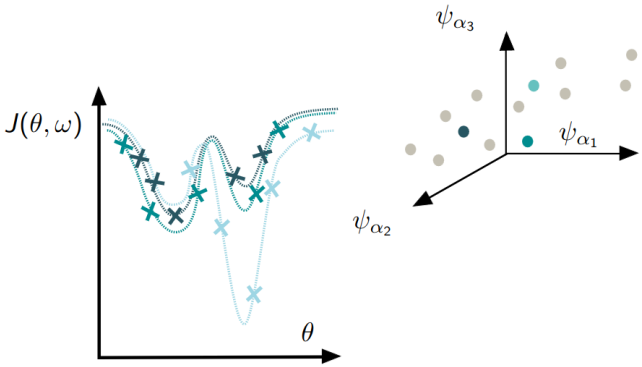
$\longrightarrow$ Stochastic metamodel

N. Lüthen, S. Marelli, B. Sudret: A spectral surrogate model for stochastic simulators computed from trajectory samples, 2023. DOI : 10.1016/j.cma.2022.115875

Methods: Stochastic metamodel



Methods: Stochastic metamodel



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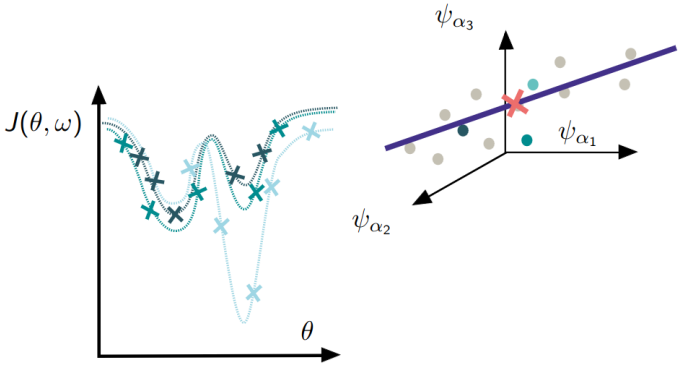

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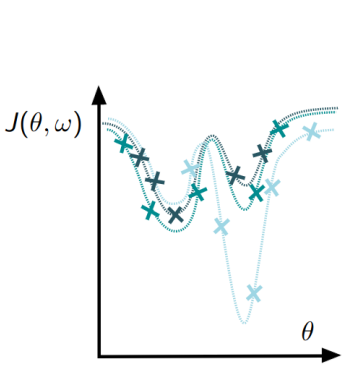

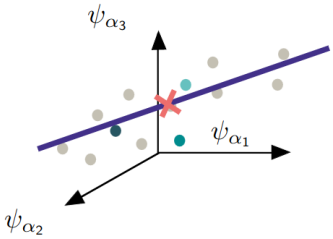

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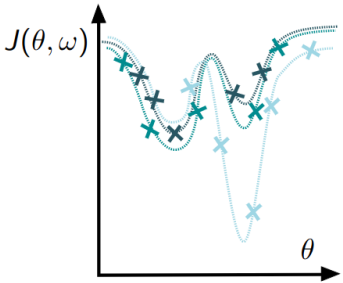

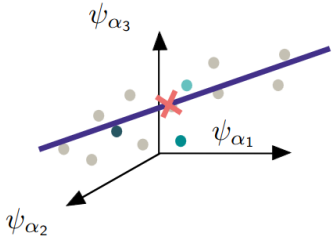

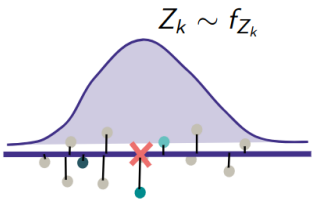

$$\hat{J}(\boldsymbol{\theta}, U(\omega)) = \hat{\mu}(\boldsymbol{\theta}) + \sum_{k=1}^{K} \sqrt{\lambda_k} Z_k(\omega) \Big(\sum_{\alpha \in \mathcal{A}} b_\alpha^{(k)} \psi_\alpha(\boldsymbol{\theta}) \Big)$$

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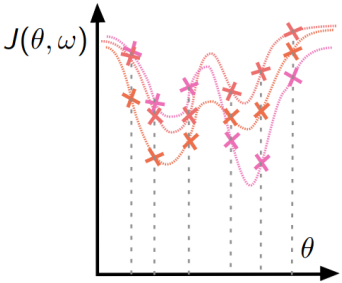

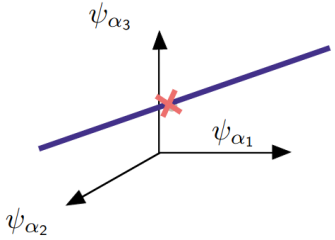

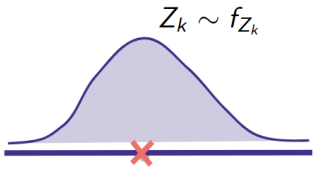

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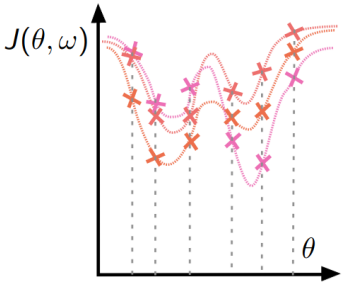

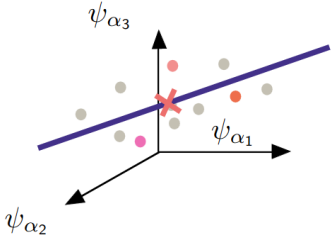

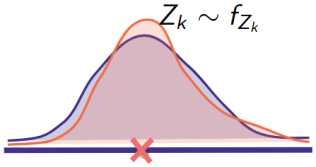

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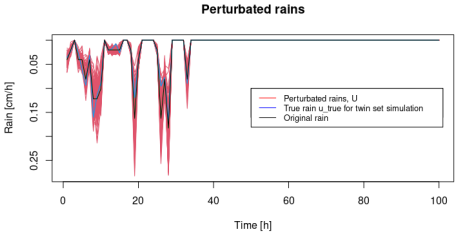
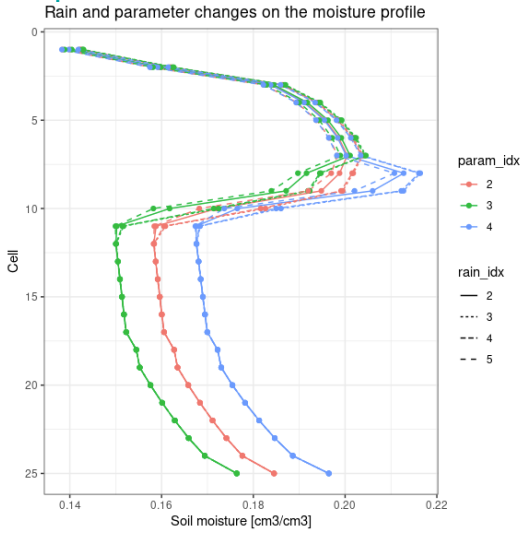
Case study: Moisture profile observations

$$\boldsymbol{\theta} \in \mathbb{R}^2, y_{true} \in \mathbb{R}^{25}$$

$$J(\boldsymbol{\theta}, u) = (\mathcal{M}(\boldsymbol{\theta}, u) - y_{true})^2$$

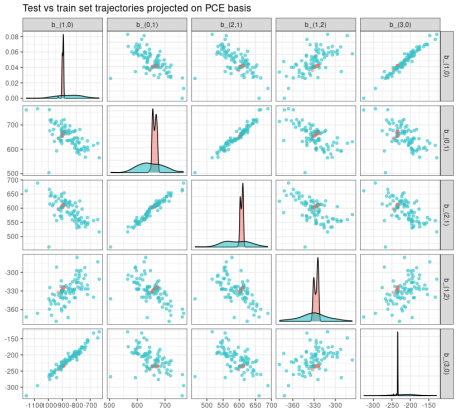


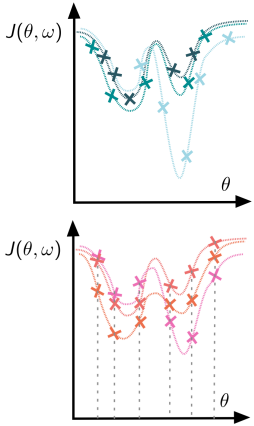
The impact of rain perturbations on the observations is very small.



Results: Validation of the emulator

Compare **train** and **test** trajectories of PESHMELBA simulations, projected on the PCE basis.





The **train** set and the **test** set do not present the same variabilities, thus the emulator does not reproduce correctly the impact of rain perturbations on the cost function.

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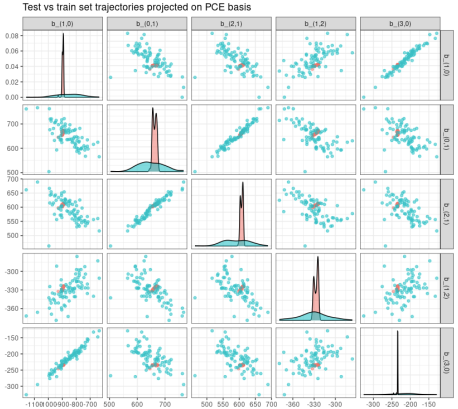

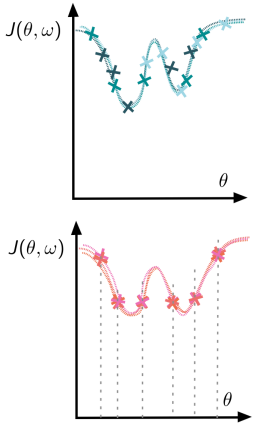

The **train** set and the **test** set do not present the same variabilities, thus the emulator does not reproduce correctly the impact of rain perturbations on the cost function.

Improvements on the emulator ?

- augment rain perturbations on the cost function (true rain measurements on the Yzeron catchment)
- use a training set, where all the experimental designs on each rain are the same
- observe another output, more sensible to rain perturbations than moisture profiles

Thank you for your attention !