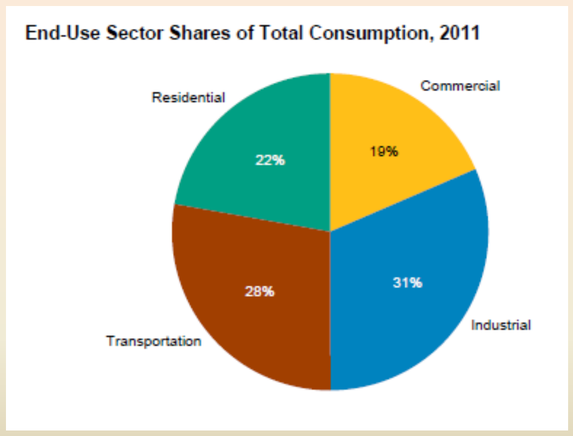
About Uncertainties in an Energy Simulation Software: EnergyPlus

Context and Goals

Context:

- High level of energy consumption in the building sector in the US (41%)
- Improve thermal qualities of the existing buildings (retrofits)
- Construct new buildings consuming less energy
- GeorgiaTech workshop: "Risk Conscious Design and Retrofit of Buildings for Low Energy "



Energy consumption by sector in the US

My objectives at the Lab:

- Characterize the different forms of uncertainty and variability in the simulation software
- Identify the underlying causes of differences between measurement and simulation

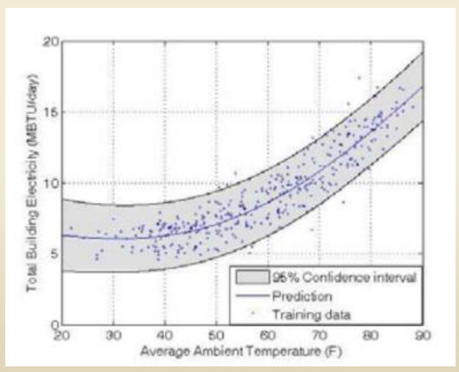
Softwares used:

- EnergyPlus
- R
- Matlab

Gaussian Processes

Conditions aux limites:

- Build a model from the measurements
- Non parametric statistical regression
- Highly flexible: let the data speak by themselves
- Can be used to assess the performance of a simulation software



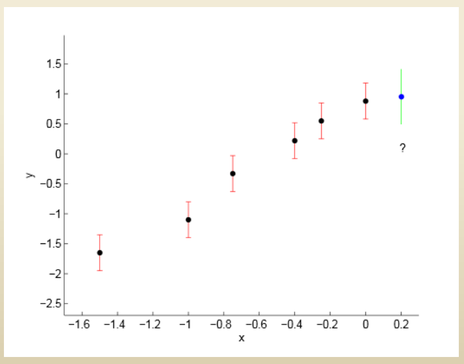
Regression cooling model

Mathematical process:

- Covariance function:

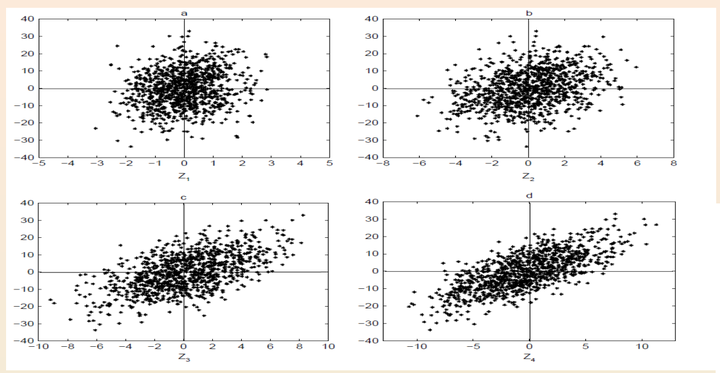
$$k(x,x') = \sigma_f^2 \exp\left[\frac{-(x-x')^2}{2l^2}\right] + \sigma_n^2\,\delta(x,x')$$

- $K = \begin{bmatrix} k(x_1,x_1) & \cdots & k(x_1,x_n) \\ \vdots & \ddots & \vdots \\ k(x_n,x_1) & \cdots & k(x_n,x_n) \end{bmatrix}$
- $K_* = [\,k(x_*,x_1) \quad k(x_*,x_2) \quad \dots \quad k(x_*,x_n)\,]$
- $K_{**} = k\,(x_*,x_*)$
- $\begin{pmatrix} y \\ y_* \end{pmatrix} \sim N\left(0\,, \begin{bmatrix} K & K_*^T \\ K_* & K_{**} \end{bmatrix}\right)$
- $y_*|y \sim N(K_*K^{-1}y\,,\; K_{**} - K_*K^{-1}K_*^T)$
- **Best estimate:** $\overline{y_*} = K_*K^{-1}y$
- **Uncertainty**: $var(y_*) = K_{**} - K_*K^{-1}K_*^T$



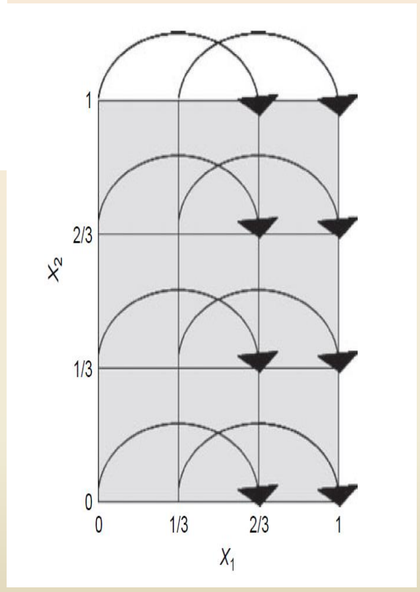
Toy model for the gaussian processes

Input Uncertainties



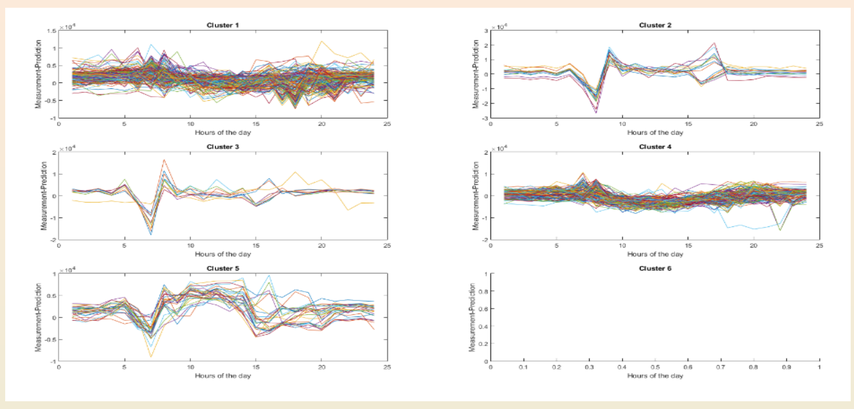
The scatterplots method

- **Saltelli**: "The study of how uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input."
- **Sensitivity analysis methods**: Monte Carlo, Scatterplots, Sigma normalized technics, Elementary effects
- **Uncertainty propagation methods:** Monte Carlo, full factorial numerical integration, univariate dimension reduction, polynomial chaos expansion

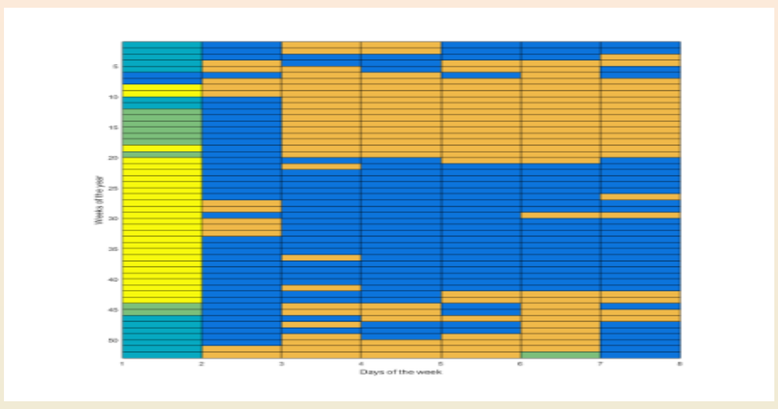


The Elementary Effect Test

Model form uncertainties



Days clustered



Results of the slustering

Model form uncertainties

- **Definition**: discrepancy associated with the ignorance and/or simplification of the real world processes
- Statistical method of model calibration

Clustering

- Study based on VizBem
- 2 methods used: crisp c-means and fuzzy c-means

Conclusion and next steps

Conclusion:

- Complete study of the uncertainties related to a simulation software (EnergyPlus)
- Algorithms developped in the fields of fault detection and errors patterns detection.

Next steps:

- Automated way to characterize the model form uncertainty
- Automated method to find out the optimal number of clusters
- Try other clustering techniques in order to be adaptable to more case studies

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