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USING THE SENSITIVITY ANALYSIS AT THE DESIGN STAGE A CASE STUDY FOR PASSIVE COOLING IN AN URBAN TROPICAL ENVIRONMENT

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Objectives

The main objective is to use sensitivity analysis to help designers and technical engineers in the early design stage of a building refurbishment or new construction.

- A three successive steps methodology is proposed :
- 1st step : energy balance of the case study.
 - 2nd step : qualitative phase to determine the best compromise between output model accuracy and computation time.
 - 3rd step : quantitative phase to deduce building design advices.



Figure 1 : Current building

Building description

Building case :

- Refurbishment project
- An office building located in Saint-Pierre in the Reunion Island.
- Methodology applied only on the 1st floor of a three-floor building
- 8 principle thermal zones.



Figure 2 : Refurbished and extended building

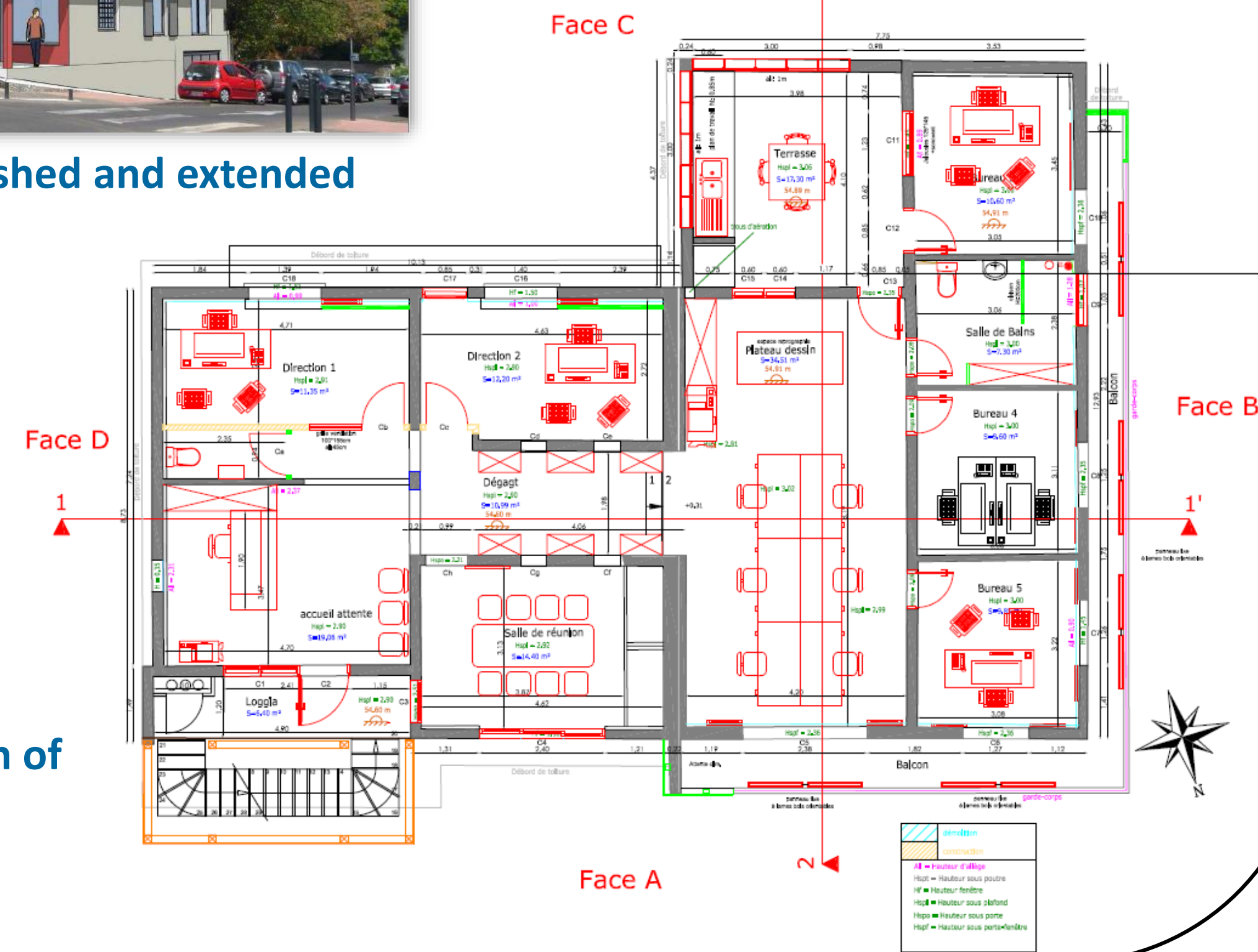


Figure 3 : 2-D plan of the 1st floor

Step 1 : Energy balance

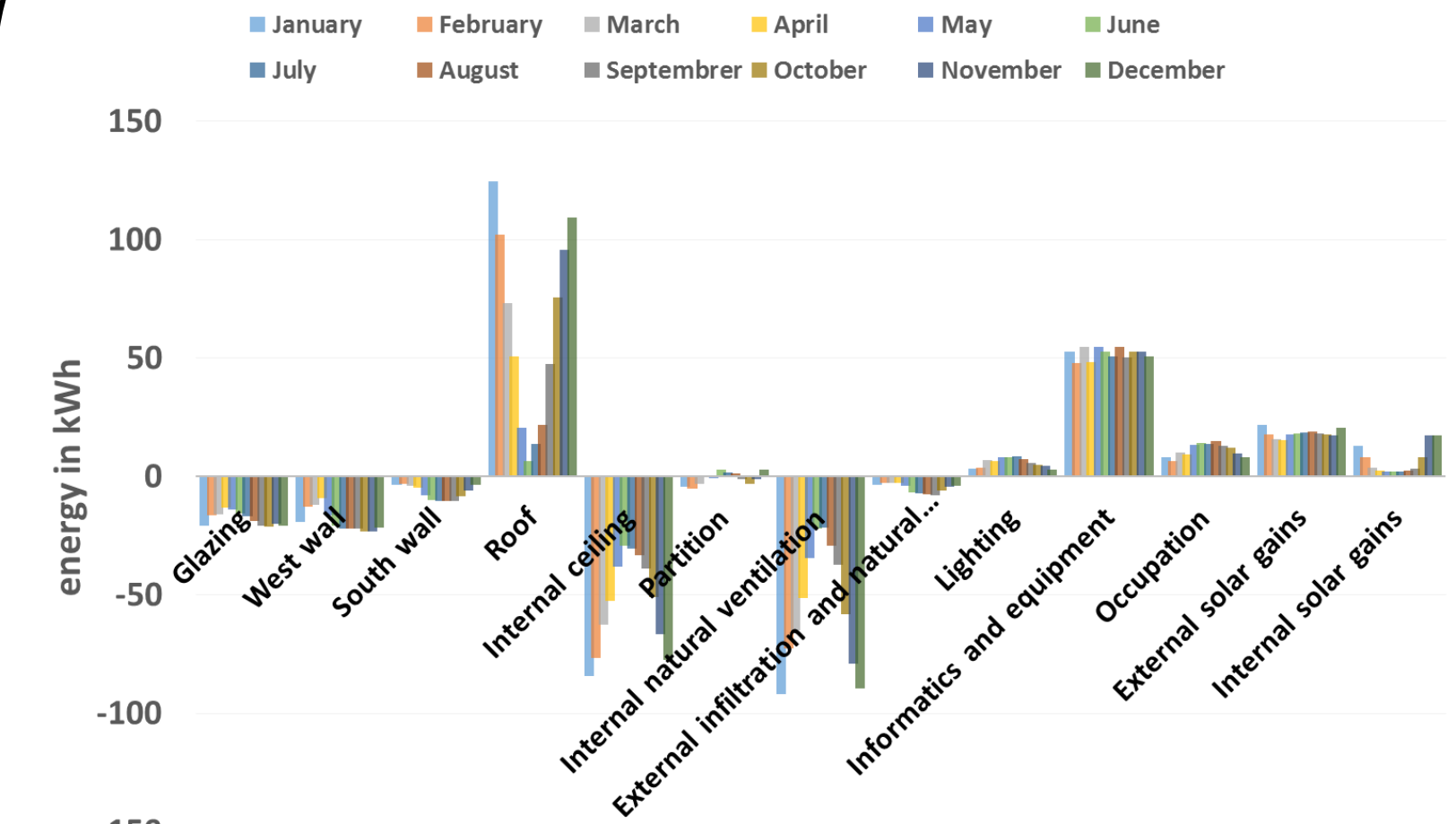


Figure 4 : Energy balance in the South-West office room

Information deduced from the energy balance

- Monthly variation.
- Large impact of :
 - natural ventilation.
 - solar gains.
 - floor and roof.
- Internal gains caused by occupation.
- Different impacts from the orientation of walls.

At the design stage, designers and technical engineers focus their interest on the building envelope.

Methodology

Building simulation hypothesis:

- EnergyPlus software for building simulation.
- 42 relevant input parameters deduced from the energy balance (opening factor, insulation thickness, concrete thickness, absorptivity, emissivity, solar factor, glazing thermal factor, shading, ...).
- Inner temperature is fixed to 28°C in the ground floor and in the second floor.
- Only natural night ventilation from 9 p.m to 8 a.m is authorized.
- All the windows have the same opening factor and during the night, internal doors are opened.
- Multizone description of the building.
- Two simulation periods corresponding to summer and mid-season weather sequences:
 - From 01/01 to 06/01 : summer period
 - From 15/04 to 28/04 : mid-season period

Objective indicator : the zone thermal comfort

- Higher the indicator, higher the thermal comfort.

$$Ind_{zone} = \frac{\sum_{t=1}^{t_{final}} T_{op,occ}^t - \sum_{t=1}^{t_{final}} T_{op,occ}^t > 27^{\circ}C}{\sum_{t=1}^{t_{final}} T_{op,occ}^t}$$

(2) Phase Screening : Morris method

- Determination of the relevant simulation period
- Determination of the relevant building zoning

Figure 5 : 2nd step with the qualitative phase

(3a)

Sensitivity coefficients allowing to give the variation direction of the assumed monotonic output considering each input parameters

(4)

Building design advices for technical engineers

Figure 6 : 3rd step with the quantitative phase

Step 2 : qualitative phase : Morris method

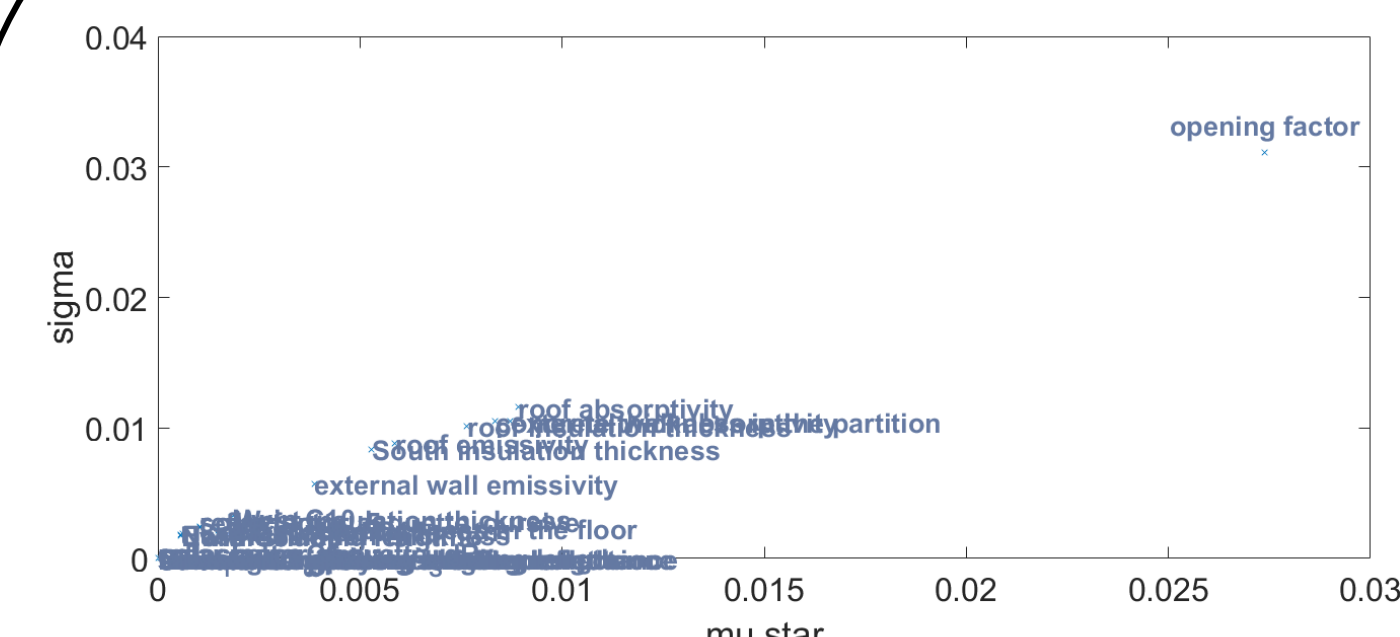


Figure 7 : Morris results in the South-West office room in January

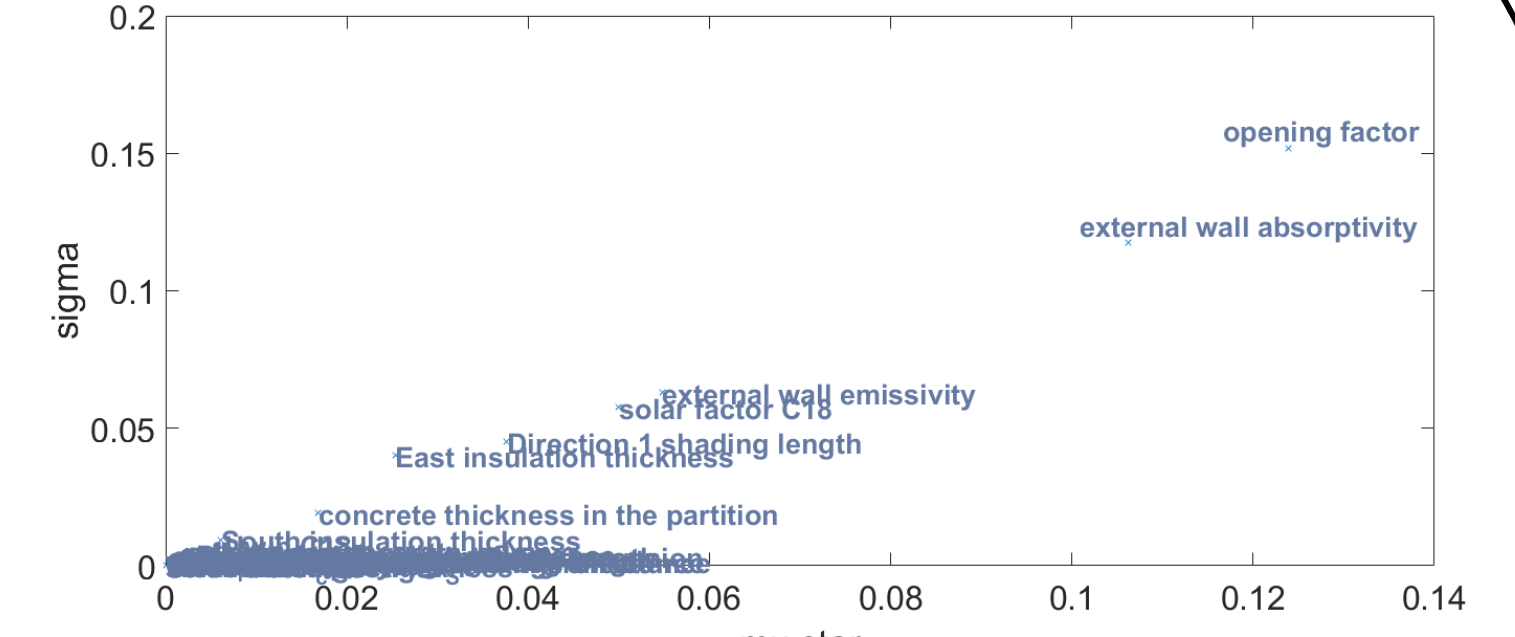


Figure 8 : Morris results in the South-East office room in April

Specific weather sequences justified by the large difference in the Morris results considering each simulation period.

Multizone description justified by the large difference in the Morris results considering each zone.

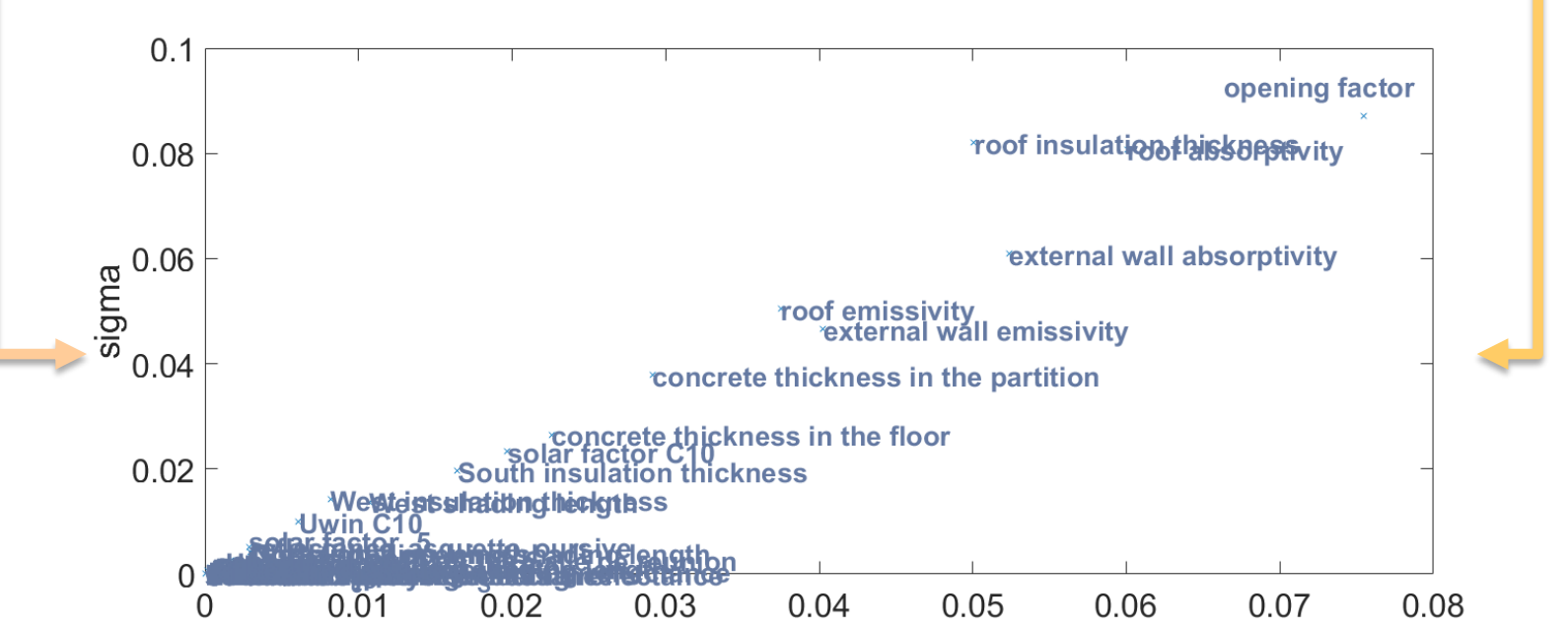


Figure 9 : Morris results in the South-West office room in April

Step 3a : Quantitative phase with SRC method

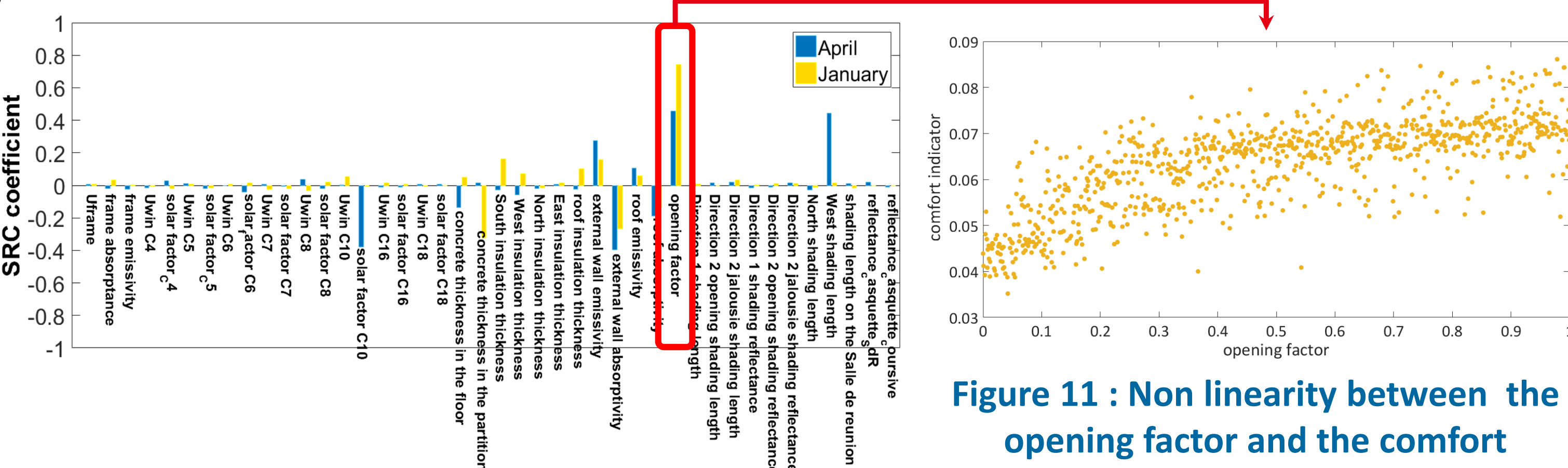


Figure 10 : SRC results in the South-West office room

Non linearity of the comfort indicator considering the opening factor parameter

Figure 11 : Non linearity between the opening factor and the comfort indicator in the South-West office room in January

Step 3b : Quantitative phase with MARS/ANOVA method

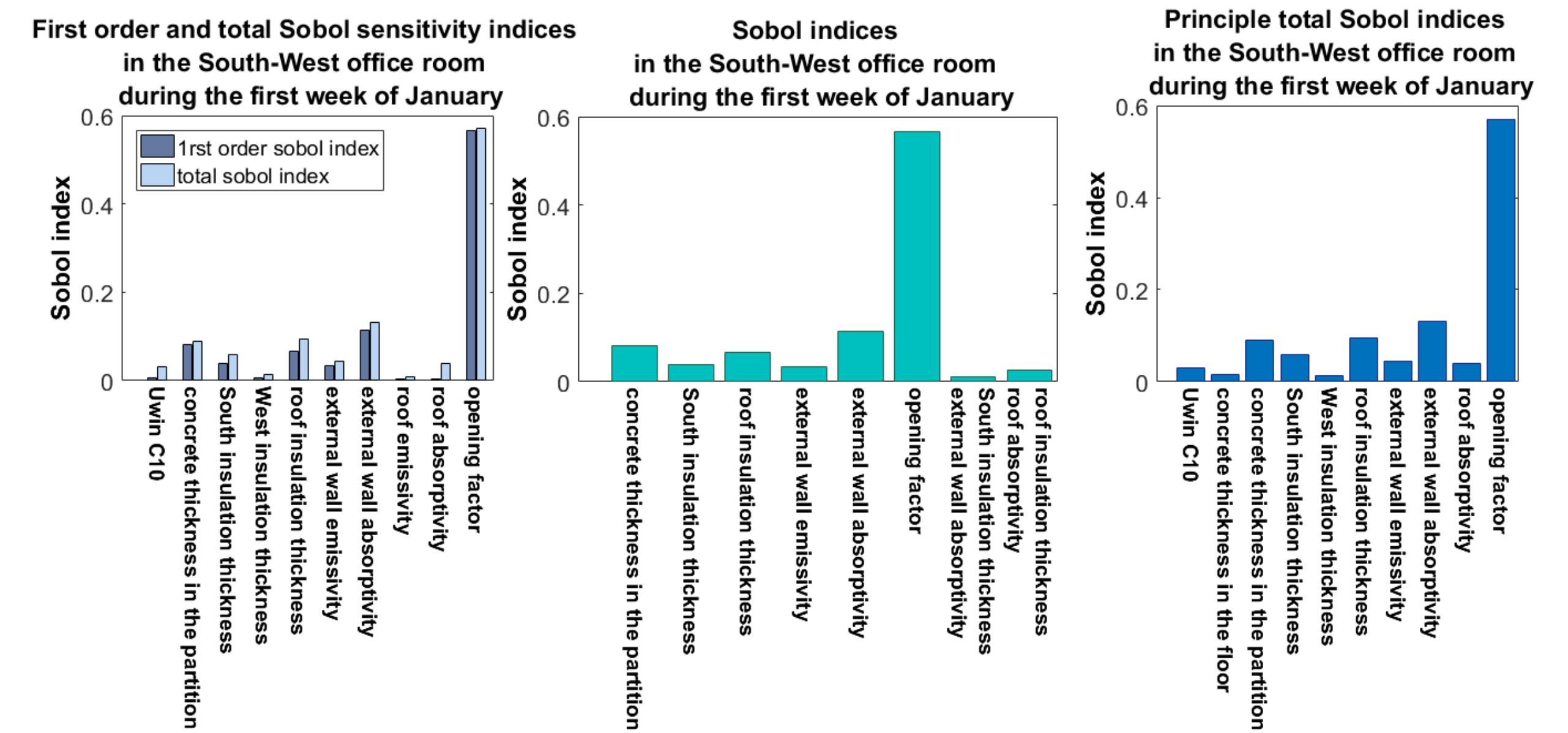


Figure 12 : Sobol indices in the South-West office room in January

Step 4 : Building design advices

- The opening factor is the most influent parameter during the summer period.
- A large concrete thickness in the partition is not favorable toward thermal comfort because of the small external temperature daily amplitude.
- The solar factor and the length of shadings are influent only during the mid-season.

Conclusion and perspectives

1. Sensitivity analysis has been used at the design stage of a building refurbishment in order to propose design advices to improve the thermal comfort in a tropical environment.
2. SA allowed to show the requirement to simulate the multizone building description in order to be able to guarantee thermal comfort for each zone.
3. SA allowed to show the requirement to consider specific weather sequences in order to be able to propose a compromise ensuring thermal comfort all over the year.
4. Perspectives would be to improve the robustness of the methodology in order to implement an easy-to-use tool intended to designers and technical engineers.

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