# Sensitivity Analysis for an Effective Transfer of Estimated Material Properties from Cone Calorimeter to Flame Spread Simulations

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## Introduction

Flame spread models based on temperature-dependent pyrolysis rates require numerous material properties as input parameters. These parameters are typically derived in an inverse modelling process (IMP) using data from bench scale experiments such as the Cone Calorimeter (CC), see Figure 1. The estimated parameters are then transferred to flame spread (FS) simulations, where a self-sustained spread is expected to occur [1].

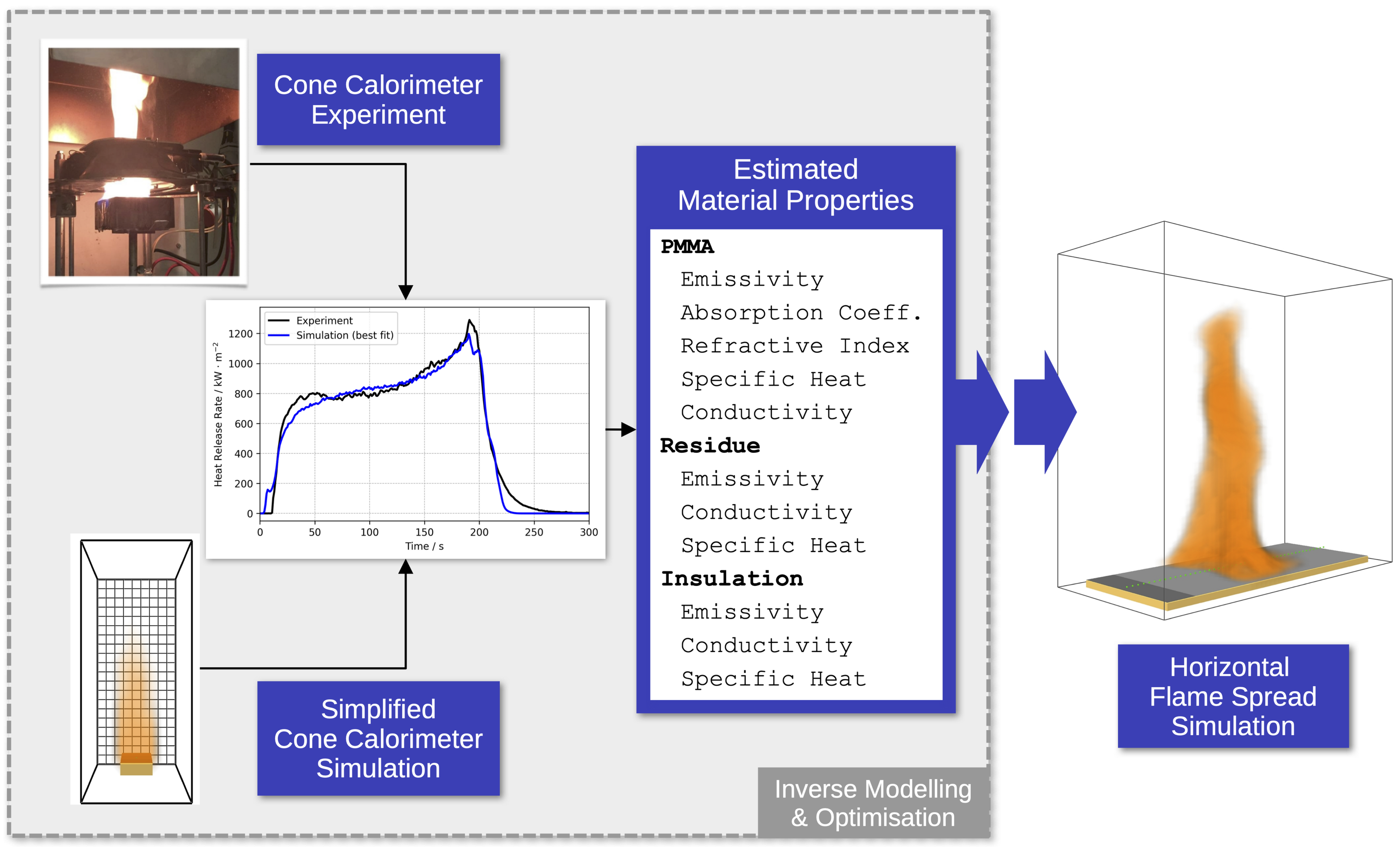


**Figure 1:** *Transfer of estimated parameters based on CC experiments to FS simulations.*

A fundamental requirement for this transfer is that the simplified CC model used in the IMP is sufficiently sensitive to the input parameters that are important to the FS simulation. Otherwise, the estimated parameters will have an increased associated uncertainty that will be transferred to the FS simulation. This is investigated here using a variance-based global sensitivity analysis method, the Sobol indices [2].

## Methodology

Sensitivities of a simplified CC and of a horizontal FS simulation to a set of 15 effective material properties are compared [3]. First- and total-order sensitivity indices (S1 and ST, respectively) are used to express the effects of each input parameter on the simulated heat release rates (HRRs), on the mean rate of spread (MRS), and on the root mean square error (RMSE), commonly used as a cost function in the optimisation. The methodology steps are shown in a flow diagram in Figure 2.

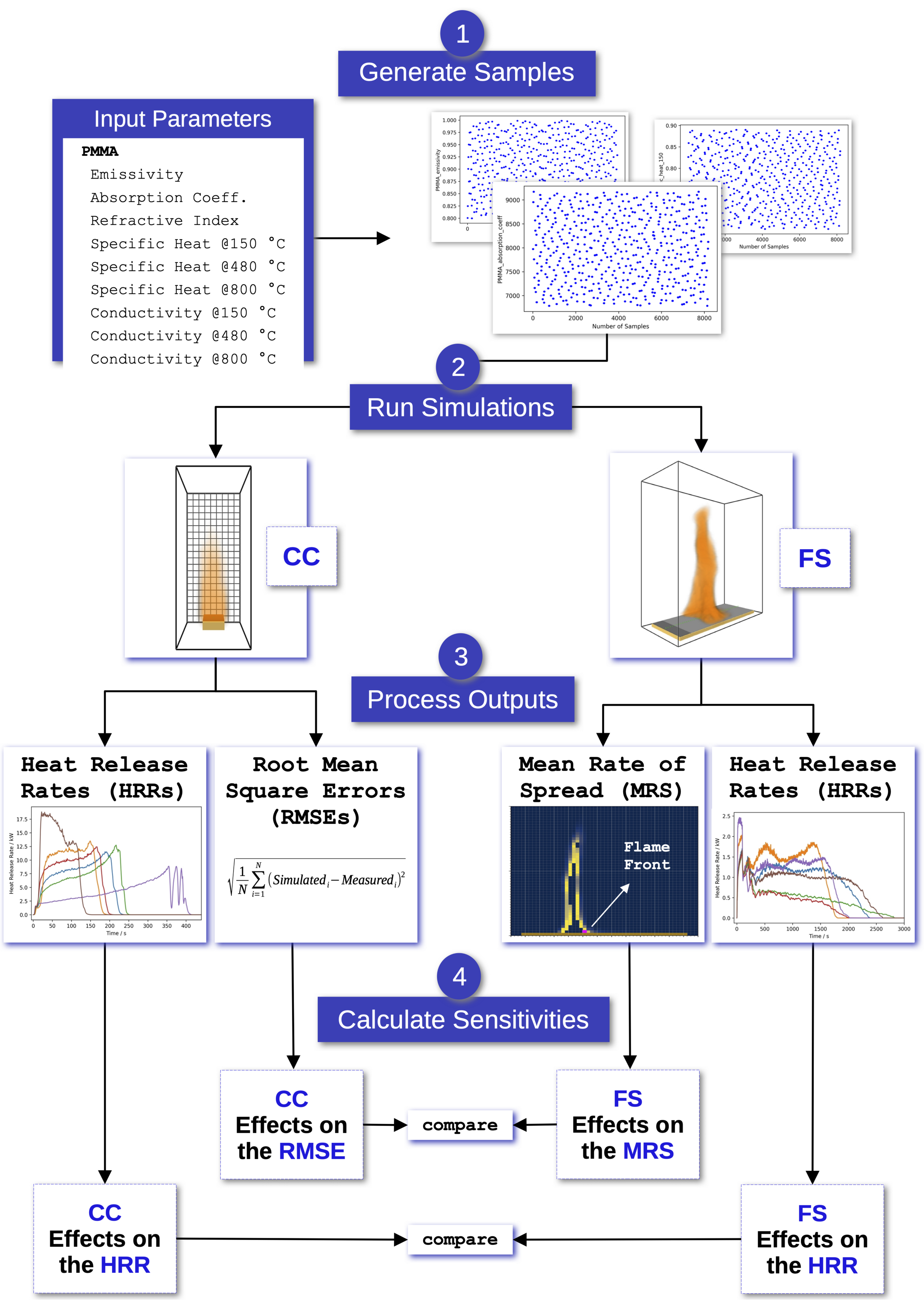


**Figure 2:** *Methodology procedure to calculate the Sobol indices and compare the effects of input parameters on different types of simulation outputs.*

## Results and Discussion

The time series of ST indices show that the relative importance of input parameters to the HRRs vary over the course of the simulations, see Figure 3. At the beginning, the HRR of the CC simulation is briefly influenced by emissivity, conductivity and specific heat, but becomes dominated by two temperature-dependent values of specific heat (Figure 3a) after about 25 seconds. Very similar behaviour is observed in the FS setup up to 100 seconds, because ignition is modelled as in the CC. After that, the external heat flux is cut, and self-sustained spread starts. This transition is clearly visible in the change in parameter importance (Figure 3b).

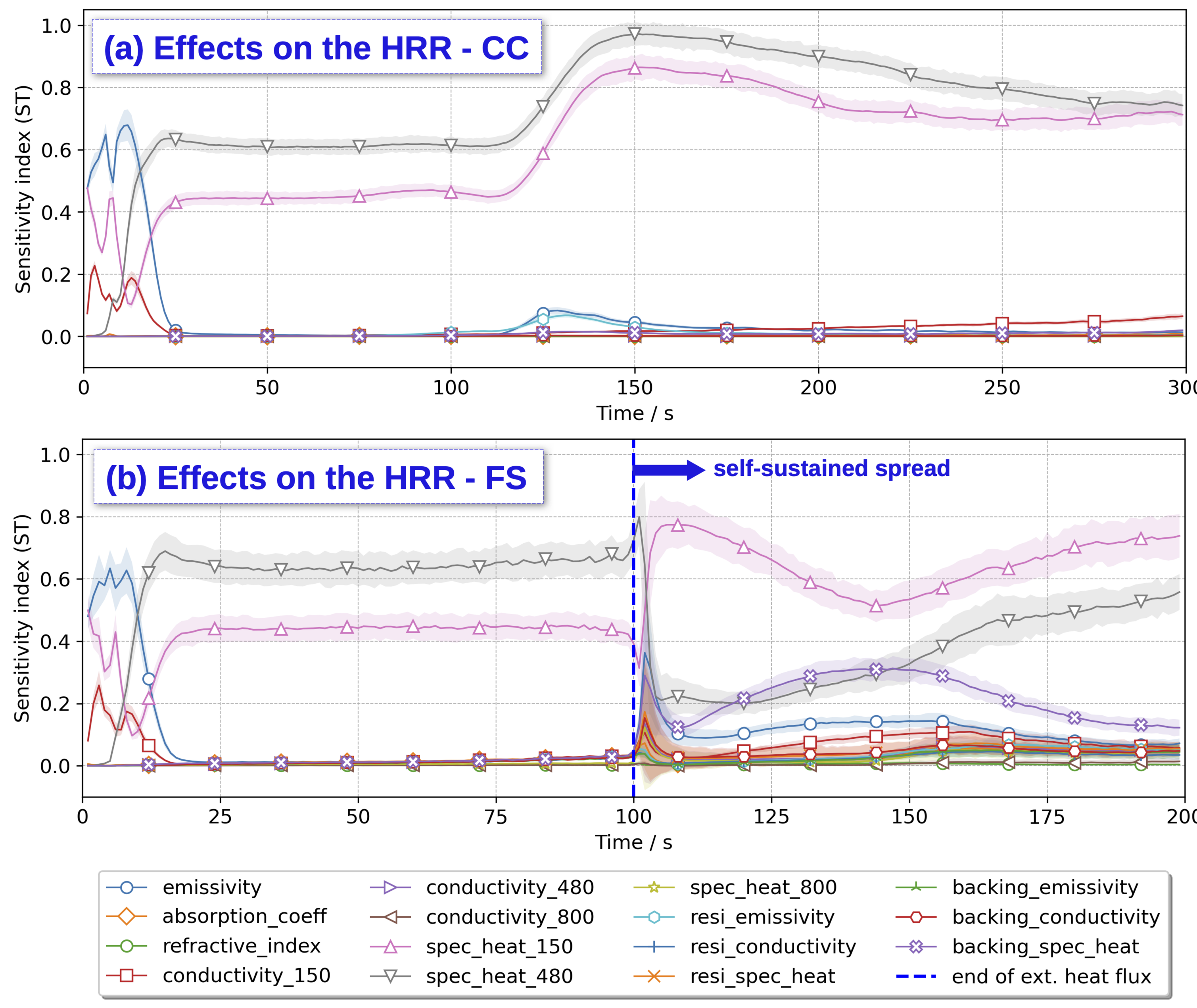


**Figure 3:** *Effects of input parameters on the simulated HRRs.*

The effects of the input parameters on single-value outputs (RMSE and MRS) from both setups are presented in Figure 4. It is shown that only the values of specific heat at 150 °C and at 480 °C seem to influence the RMSE through strong interaction effects, due to the negligible S1 and dominant ST values, see Figure 4a. The MRS on the other hand seems to be able to capture the time-varying importance of other parameters which mostly affected the self-sustained spread phase, as shown in Figure 4b.

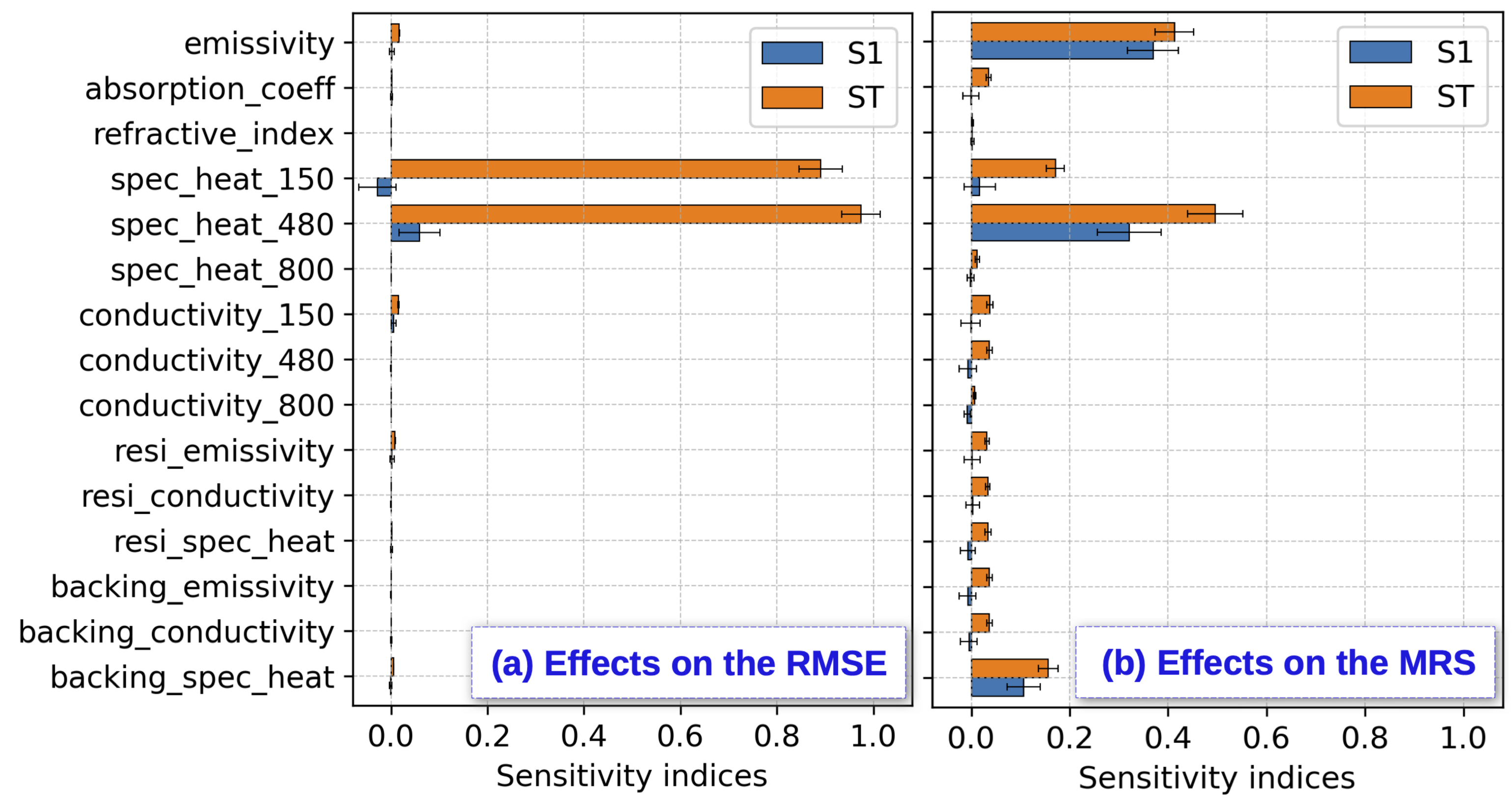


**Figure 4:** *Effects of input parameters on the RMSE and on the MRS.*

## Conclusion

The sensitivity analyses conducted in this study have shown that the discrepancies between the simplified CC and the horizontal FS simulation are significant. Simulation outputs from both setups respond differently to changes in the same set of input parameters, due to differences between the CC and the FS heating conditions. More importantly, these differences are aggravated when the HRR of the CC simulation is condensed in a single RMSE value, diminishing the momentary significance of some parameters. As a consequence, such parameters cannot be well estimated in the optimisation, and will compromise the FS simulation by carrying over larger associated uncertainties.

## References

[1] T. L.S. Quaresma and T. Hehnen and L. Arnold. Sensitivity Analysis for an Effective Transfer of Estimated Material Properties from Cone Calorimeter to Horizontal Flame Spread Simulations. *Submitted to: Fire Safety Journal*, 2023.

[2] I. Sobol. Global sensitivity indices for nonlinear mathematical models and their Monte Carlo estimates. *Mathematics and computers in simulation*, 55(1-3):271–280, 2001.

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