Aalto University
School of Science
and Technology

Compensating model uncertainty in probabilistic fire simulations

DEEPAK PAUDEL

SIMO HOSTIKKA

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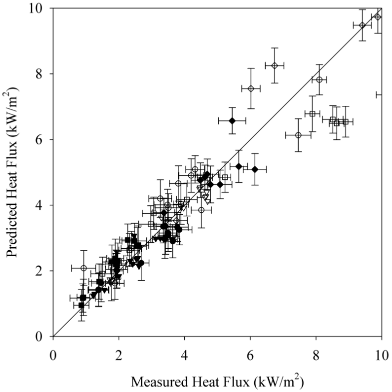
Introduction

- **No model is 100% accurate**
- **Fire simulation uncertainty:**
  Smoke det. time: $\simeq$ 5%
  Temp. pred.: $\simeq$ 10%
  Smoke conc.: $\simeq$ 20%



- **Uncertainty sources:**
  Model error: Simplification, physics, numerical error
  Parameter error: Exact values of inputs are not known

Introduction

- **For a validated model, the general trend of modelling error is known**

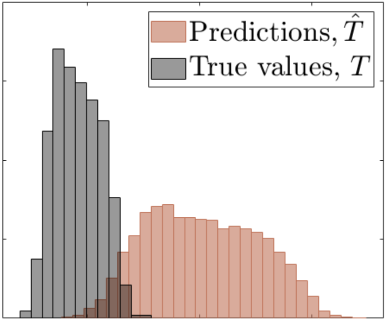
- **Systematic bias, δ**

$$\delta = \frac{\mu_{\hat{T}}}{\mu_T}$$

- **Variance of error, $\widetilde{\sigma}_\epsilon$**

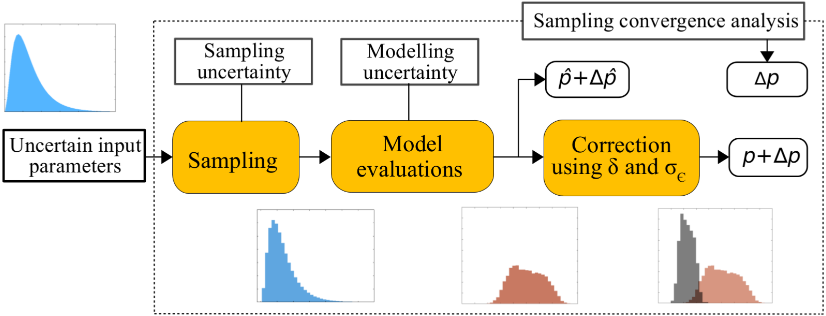
$$\epsilon_i = \hat{T}_i - \delta \cdot T_i$$

$$\sigma_\epsilon^2 = \frac{1}{N} \sum_{i=1}^{N} \epsilon_i$$



Objective

To use δ and $\widetilde{\sigma}_\epsilon$ to improve the accuracy of probabilistic simulations.

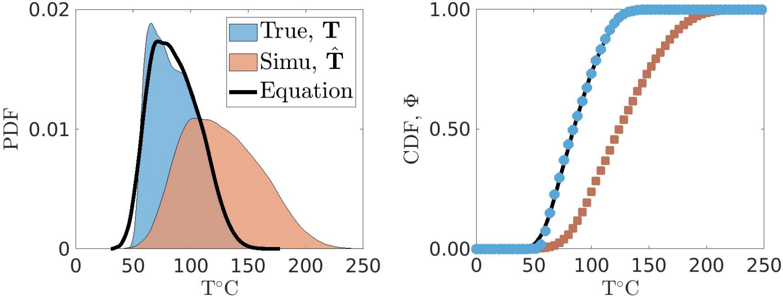


Method

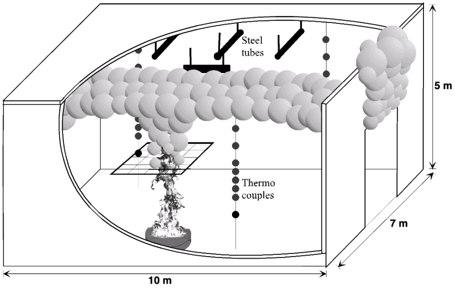
Uncertainty model:

$$\hat{T} = \delta T + \epsilon \Rightarrow \qquad \mu_{\hat{T}} = \delta \mu_{T}, \qquad \widetilde{\sigma}^2_{\hat{T}} = \widetilde{\sigma}^2_{T} + \widetilde{\sigma}^2_{\epsilon}$$

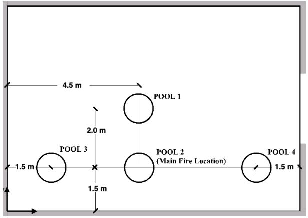
$$T = \alpha \hat{T} + \beta \Rightarrow \quad T = \frac{1}{\delta}\left[\mu_{\hat{T}} + \left(\hat{T} - \mu_{\hat{T}}\right)\sqrt{1 - \left(\frac{\mu_{\hat{T}}\widetilde{\sigma}_{\epsilon}}{\sigma_{\hat{T}}}\right)^2}\,\right]$$



Application



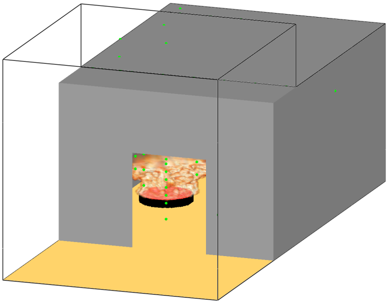
- Altogether 21 Tests with varying input conditions



- Compartment fire:

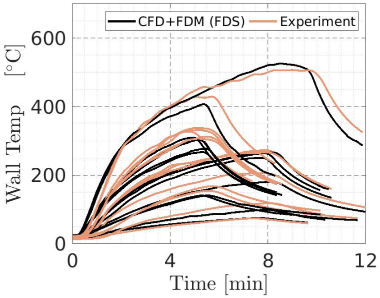
Hostikka S, Kokkala M, Vaari J (2001) Experimental study of the localized room fires: NFSC2 test series. *Technical Research Centre of Finland*, VTT Research Notes 2104.

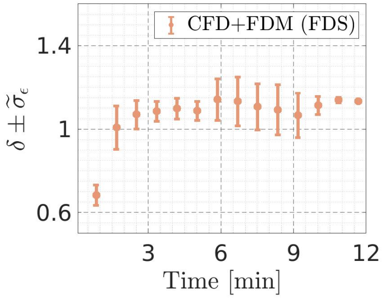
Fire Dynamics Simulator (FDS) model



- CFD and FDM based calculations.
- Resolution: 20 cm

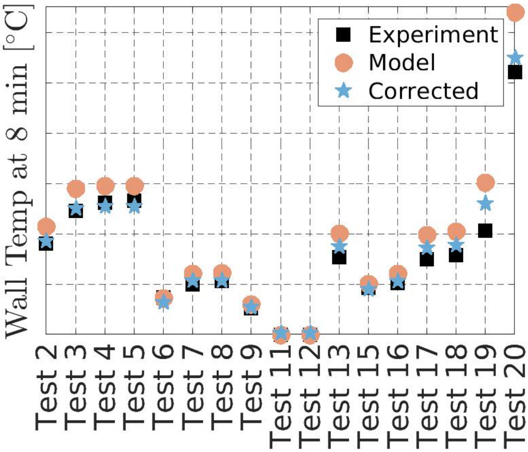
Modelling Uncertainty



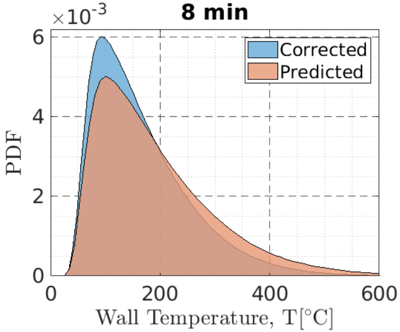


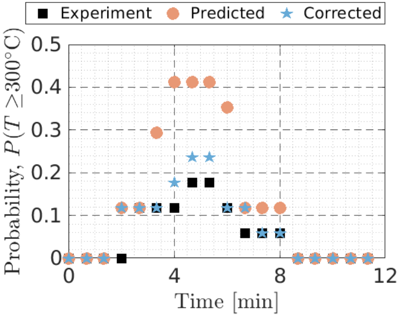
Improving predictions

- **Using δ, $\widetilde{\sigma}_\epsilon$ and the derived equation:**



Improving probabilistic outputs





Conclusion

Model uncertainties reported in the context of model validation can be used to improve the accuracy of stochastic outputs:

- Output moments, μ and σ
- Failure probabilities
- Risk estimates
- Optimal measures

Acknowledgements

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