

Lab-scale study of radiative fluxes received from a fire front

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Abstract. Numerical simulations of radiation received from a fire front were carried out in a situation of laboratory-scale fire. The fire front was determined at different instants based on camera images taken during a real experiment, and predicted in using a “small world network” propagation model. The fluxes were computed using either a ray tracing method with EDStaR, or a home-made reciprocal Monte Carlo method. Results were compared with available flux measurements using radiative heat flux gauges.

1. Introduction

Radiative transfer is one of the leading mechanisms in fire propagation. It is also a key transfer mode when evaluating the possible hazards due to fire spread. The building rules and the size of the area free of vegetation must be determined considering the impact of radiative fluxes on the houses. This is of particular interest for countries where urban areas are inter-connected with forest areas, like in France. As a preliminary step before real scale evaluations, experiments were carried out at laboratory scale on burning tables. This was indeed a first calibration step. Fire spread was studied on a configuration in which flux sensors were placed on the faces of a cube centred in a circular vegetation-free area. The fire was seen to reach and spread around the cube featuring a house and the fluxes were registered. The goal of the numerical work conducted on the same configuration was to simulate the radiative transfer and to compare the predicted fluxes on the different faces of the cube with the experimental data. For this purpose, the fire front was extracted as a function of time from camera recordings carried out during the experiment. Then a ray tracing simulation was performed using EDStaR, simulating the radiation from this fire front. In parallel a complete simulation of fire propagation was conducted using a small world network model and comparisons were carried out on the fluxes received by the target. The present communication briefly presents the setup, the simulations and first comparisons between experimental data and simulation results.

2. An overview of the experimental setup PROMETHEI

Experiments were carried out at the experimental platform PROMETHEI, which was designed by the LEMTA in Nancy to perform fire propagation tests at the laboratory scale. Burning tables 3.8 m x 3 m in size were used. The fuel was excelsior, with a vegetation load of 500 g/m². The fire was ignited on a line. A fuelbreak was considered as a circular surface with diameter 1 m and its center is located at 1.9 in X axis and 1.7 m in Y axis. A cubic structure was located at the center of this area, supporting

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radiative heat flux gauges on each face (see Figure 1). Visible cameras (one on the rear side and one on the front side) were used to identify the fire front position as a function of time. Details on the setup and on the experimental facility can be found in [1]. An example of fire front reconstruction by SWN model is presented in Figure 2 (experimental data with black and blue dots compared to fire propagation model predictions with red symbols) when the fire is propagating around the fuelbreak area.



Figure 1: Picture of the setup after fire ignition

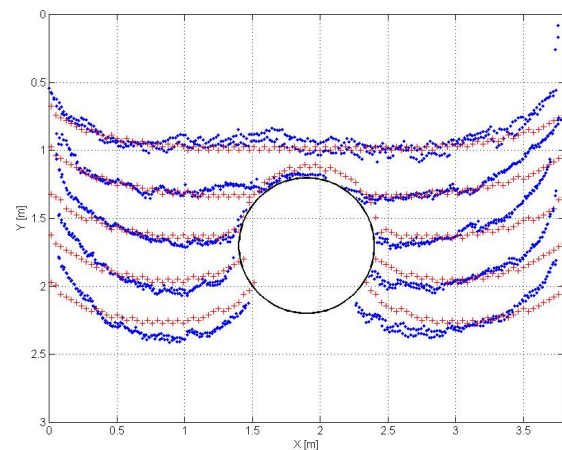


Figure 2: Example of a fire front shape reconstruction and identification as a function of time.

3. Numerical simulations

Based on the fire front reconstruction, simulations were performed for the radiative transfer with EDStaR (*Environnement de Développement Statistique Radiative*) taken from PBRT, which is a physically based rendering system based on the ray-tracing algorithm [2]. It is originally used to simulate the effect of light on a described geometry. A group of researchers from laboratories RAPSODEE, LAPLACE and PROMES, used the environment of PBRT to create EDStaR [3], with the aim of performing radiative transfer calculations. This numerical toolbox also calculates statistical errors and it is optimized for parallel calculations (MPI). The geometry of the experimental setup was computed inside EDStaR, to represent the vegetation, the box with the radiative flux detectors and a flame which follows the shape of the front fire. The flame was firstly considered as a radiant panel. A view factor was then calculated between the flame and each radiative flux detectors, with the use of the ray-tracing algorithm of EDStaR.

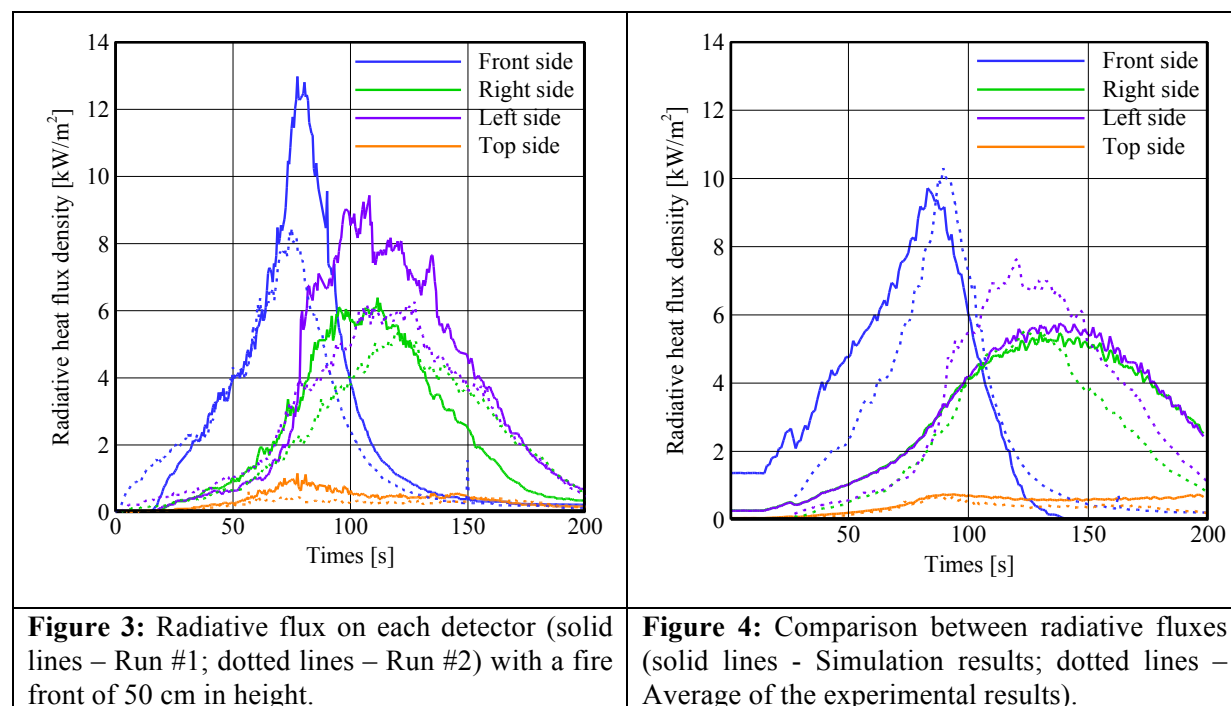
In parallel, a complete prediction of the fire propagation was done with a small-world network code [1] combined with a reciprocal Monte Carlo method simulating the radiation received by the heat flux gauges from the volume of flame. Input data required for the simulation were taken from previous experiments by the authors [1,4], namely flame temperature 1400 K, flame absorption coefficient 0.2 m^{-1} and flame height 50 cm. A sensitivity analysis is of course required in order to check the exact influence of these input data (work in progress).

4. Results and discussion

The fire propagation experiments have been repeated two times (Run #1 and Run #2) order to analyze the reproducibility of experimental results. The experimental radiative fluxes obtained are plotted in

Figure 3. The relative discrepancies can reach 50% (for the Front side detector). An average of these data between Run #1 and Run #2 is here used for the comparison with the numerical results.

Radiative fluxes were computed for the different detectors (front, lateral and top detectors). They are plotted in Figure 4 for the flame height of 50 cm, which was found to yield the lowest discrepancy between averaged experimental data and numerical results.



These are only preliminary results but it seems that the main trends are captured as the flame propagates. This method of flux simulation will be further extended in order to allow a comparison for all the fire propagation experiment.

5. Conclusions

Simulations were carried out on the fluxes received from a fire front combining a fine reconstruction of the fire front location with a ray tracing method for the radiative flux evaluation. Preliminary results show the possibility to obtain the radiative fluxes with sensitivity data for the flame geometry in particular. Further tests will be conducted for optically thin or thick flames, instead of a solid flame, involving a better description of the true flame geometry and of its emission.

References

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