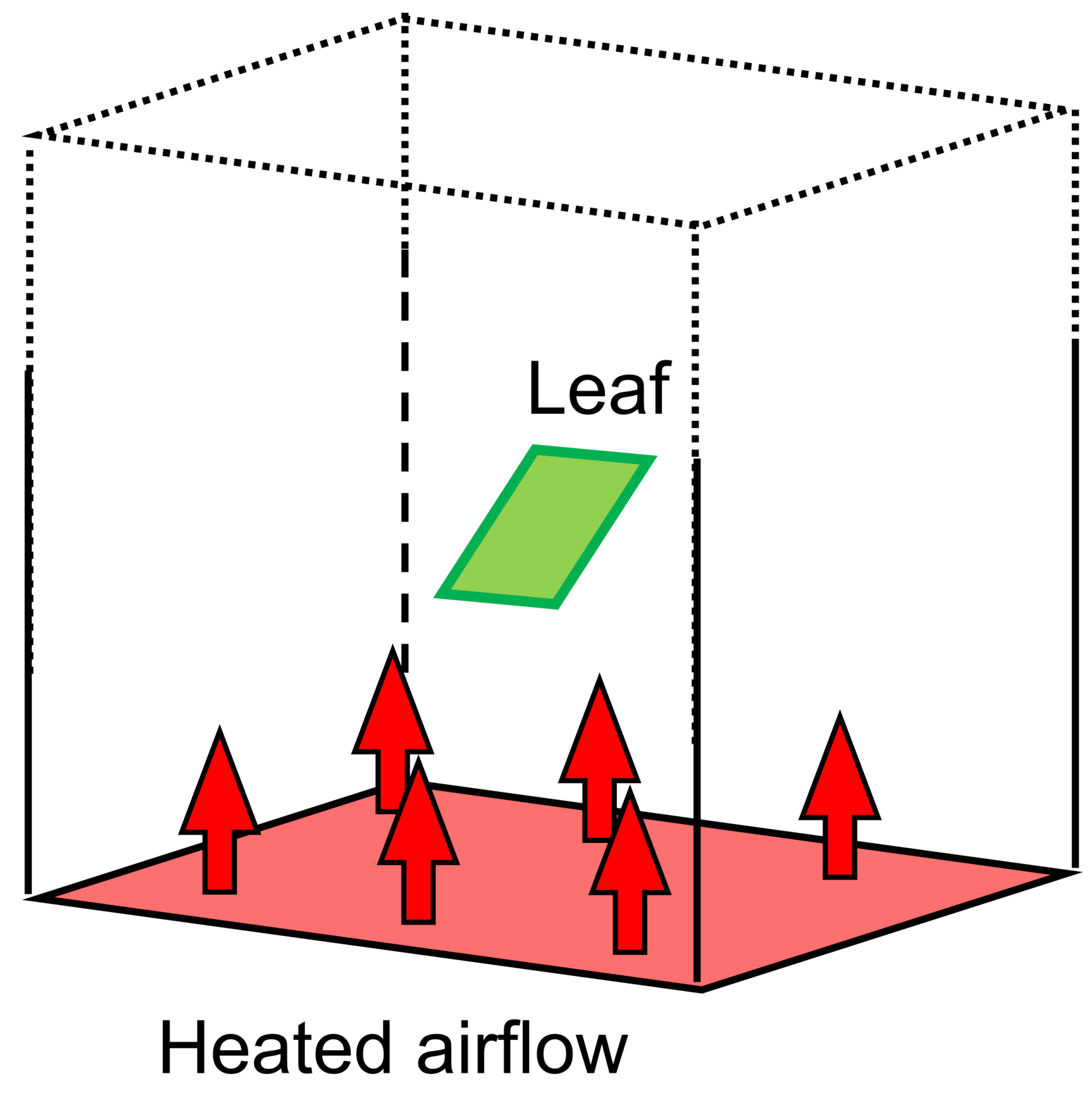
Modelling the effect of moisture content on the ignition of a single leaf

This research examines how the moisture content of vegetation influences the flammability of bushfire fuels. This will provide deeper insights into the way bushfires develop in their initial stages and their likelihood of growing into large and dangerous events.

Fig. 1*: Model Schematic*



All bushfires start with the ignition of small fuel elements, such as leaves or twigs. The flammability of these fuel elements is dramatically influenced by the moisture content of both live and dead vegetation. This project uses **advanced computational modelling** to improve our detailed understanding of how the moisture present in vegetation influences the heating, pyrolysis, ignition and subsequent combustion of a single leaf.

Model simulations were implemented using the open source FireFOAM platform with the set-up depicted in Figure 1 and utilizing supercomputing resources at NCI.

The simulations considered moisture contents of 34% and 26%. Results indicated that the drier leaf (26%) ignited around 10% faster than the moister leaf (34%) and exhibited a greater temperature increase. Moreover, after 2.5 seconds, the drier leaf produced about 1.5% more char than the moister leaf (see Figure 2).

Future work will consider additional moisture contents, different leaf geometries and orientations, and leaves of different material types. Simulation results are being compared with detailed experiments in collaboration with US colleagues.

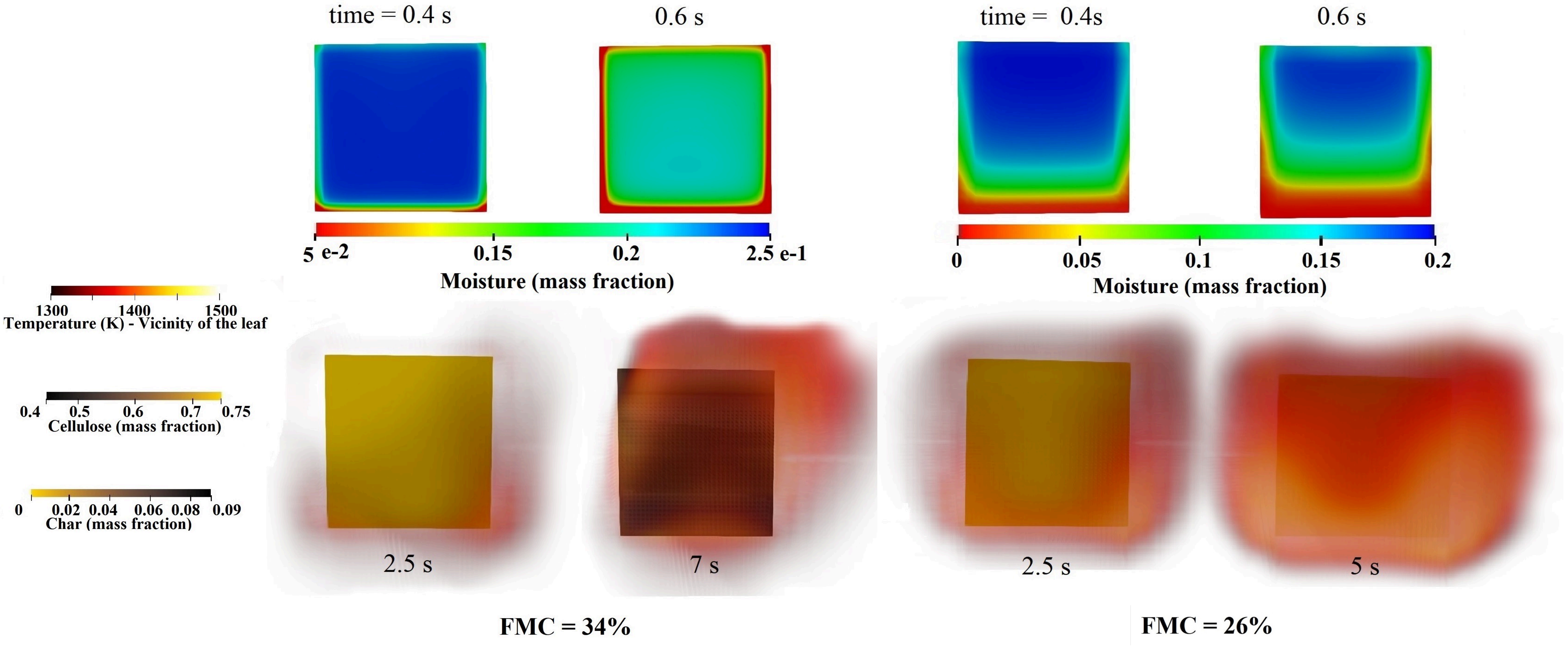


Fig. 2*: Simulation results for two different fuel moisture contents: FMC = 34% and 26%*

International collaborator:
Missoula Fire Laboratory,
US Forest Service

For more information contact:
Ali Edalatinejad or Maryam Ghodrat
<bushfire.research@unsw.edu.au>

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Computational modelling of wildfire impacts at the wildland-urban interface

This research is improving our understanding of the impacts that wildfire has on structures in the wildland-urban interface (WUI). WUI fires have disastrous impacts on people and property and structure loss from wildland fires has significantly increased over the past few decades due to increased development in rural areas and climate change.

Current standards for building in bushfire prone areas make several assumptions about the nature of bushfire at the WUI (see Fig. 1). Through advanced computational modelling, these assumptions can be tested and new insights into fire impacts can be obtained. The models incorporate the fundamentals of wildland fire spread, including the effects of convective and radiant heat transfer.

Fig. 1*: Wildfire burning in the WUI.*

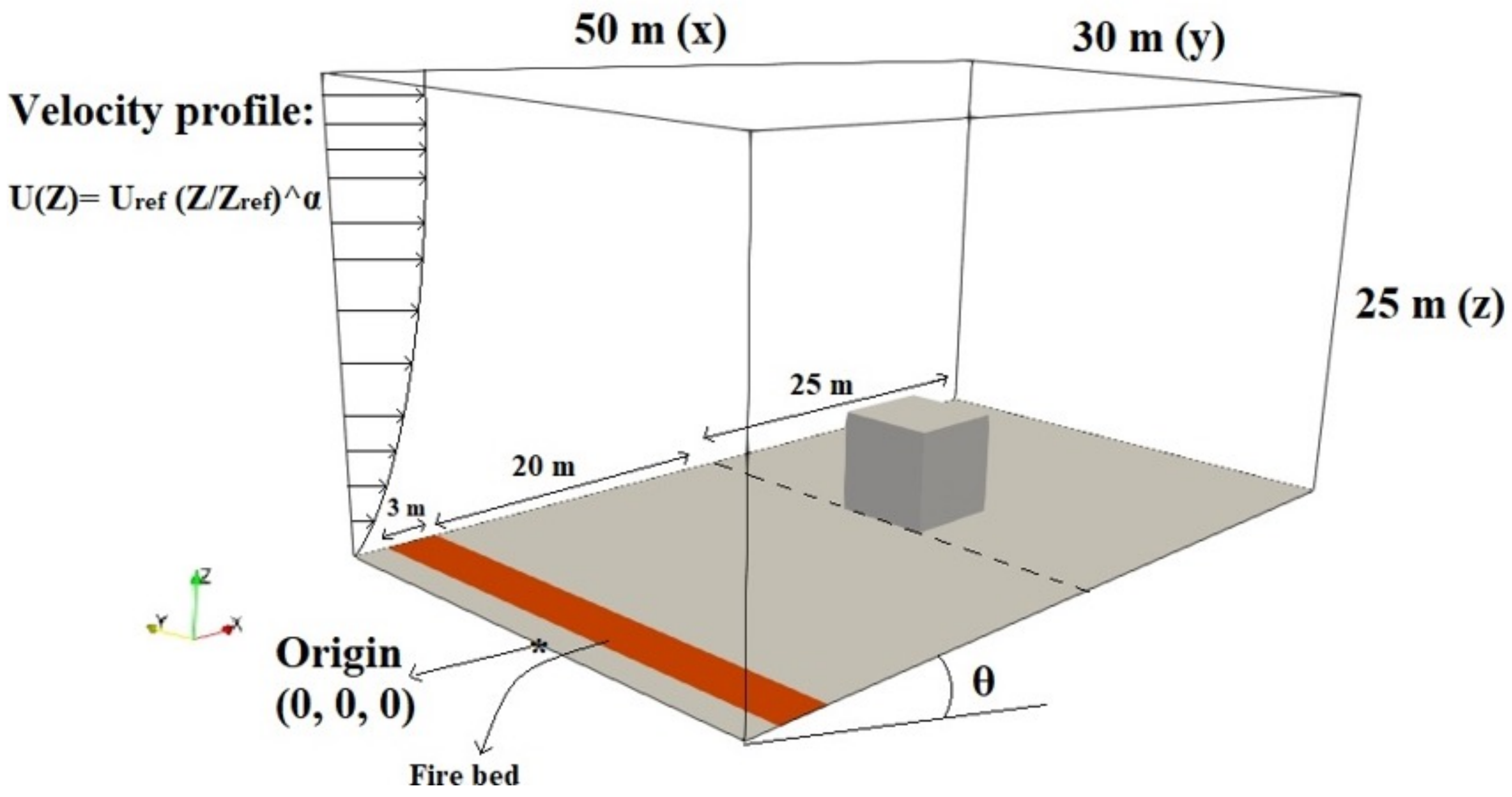


Fig. 2*: Model set-up for implementation in FireFOAM.*

The model, implemented in FireFOAM, uses computational fluid dynamics to simulate the effects of a fire on an idealized structure:

- The structure size is 6×6×6 m.
- The model domain is 50×30×25 m.
- A fire line is burning upwind of the structure.
- Different wind speeds, terrain slopes and fire intensities are considered.

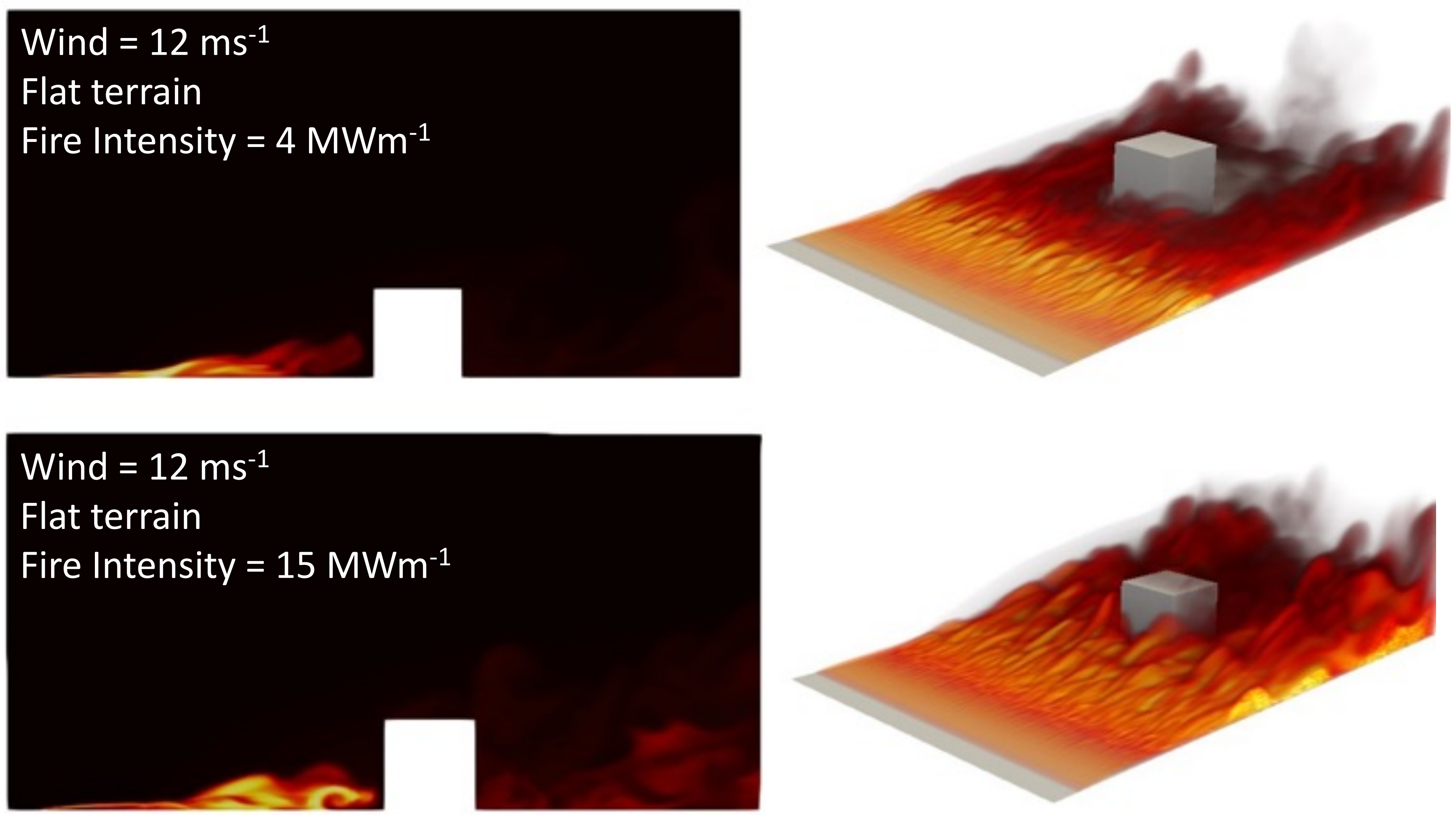


Fig. 3*: Simulated temperature distribution for fire impacting the structure under the specified wind, terrain and fire intensity conditions.*

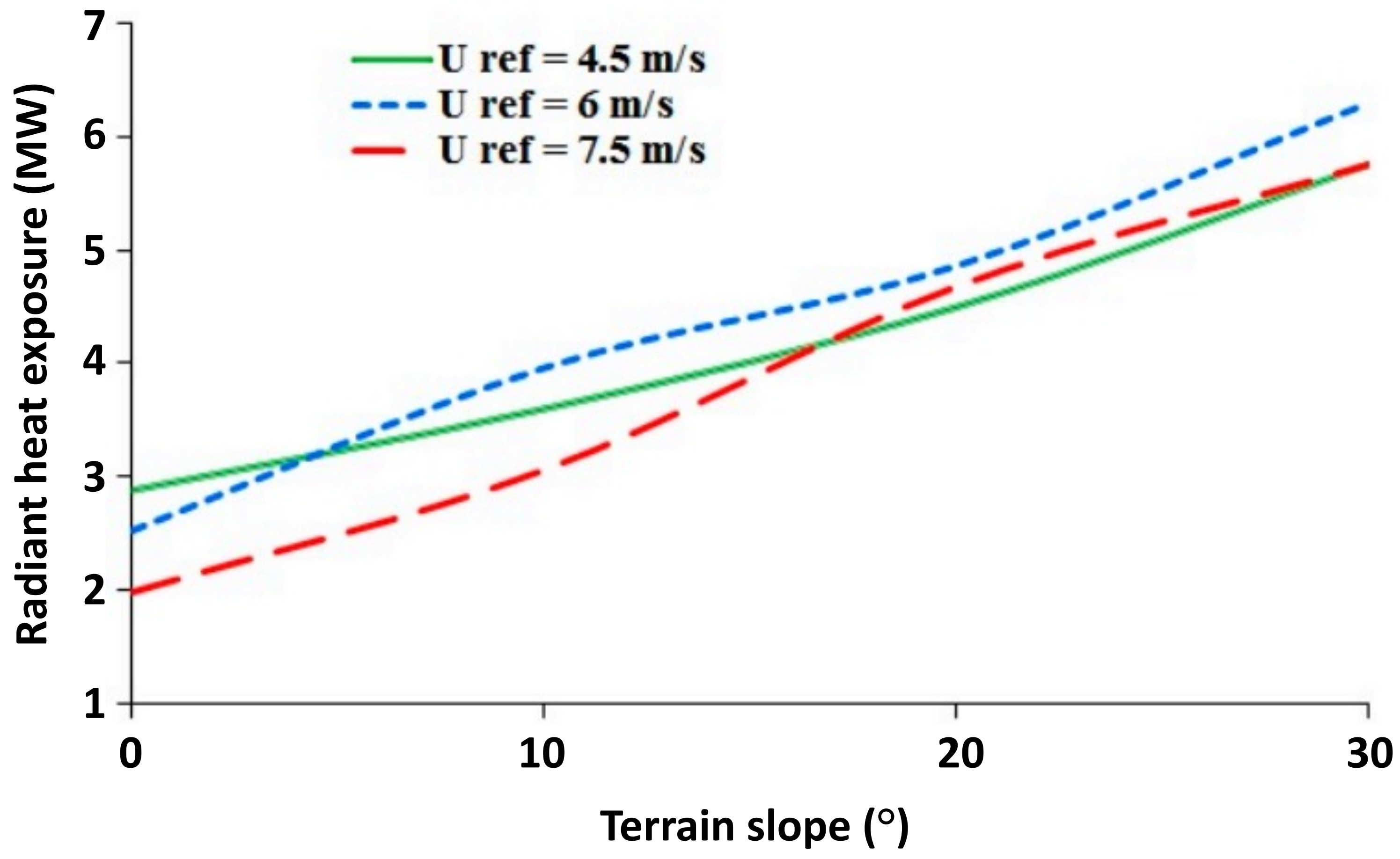


Fig. 4*: Simulated radiant heat exposure of the structure under different wind speeds and terrain slopes. The results can be used to better inform building material requirements for houses built in different parts of the wildland-urban interface.*

Collaborator:
Worcester Polytechnic Institute, USA

For more information contact:
Maryam Ghodrat
<bushfire.research@unsw.edu.au>

Find out more

Modelling convective heat transfer for a fire spreading up a slope

This research aims to quantify the convective cooling and heating effects of a propagating fire by utilizing the FireFOAM software. The outcomes of this study will significantly enhance the estimation of the impact of heat flux on the ignition process of various vegetation types located at different distances from the fire source.

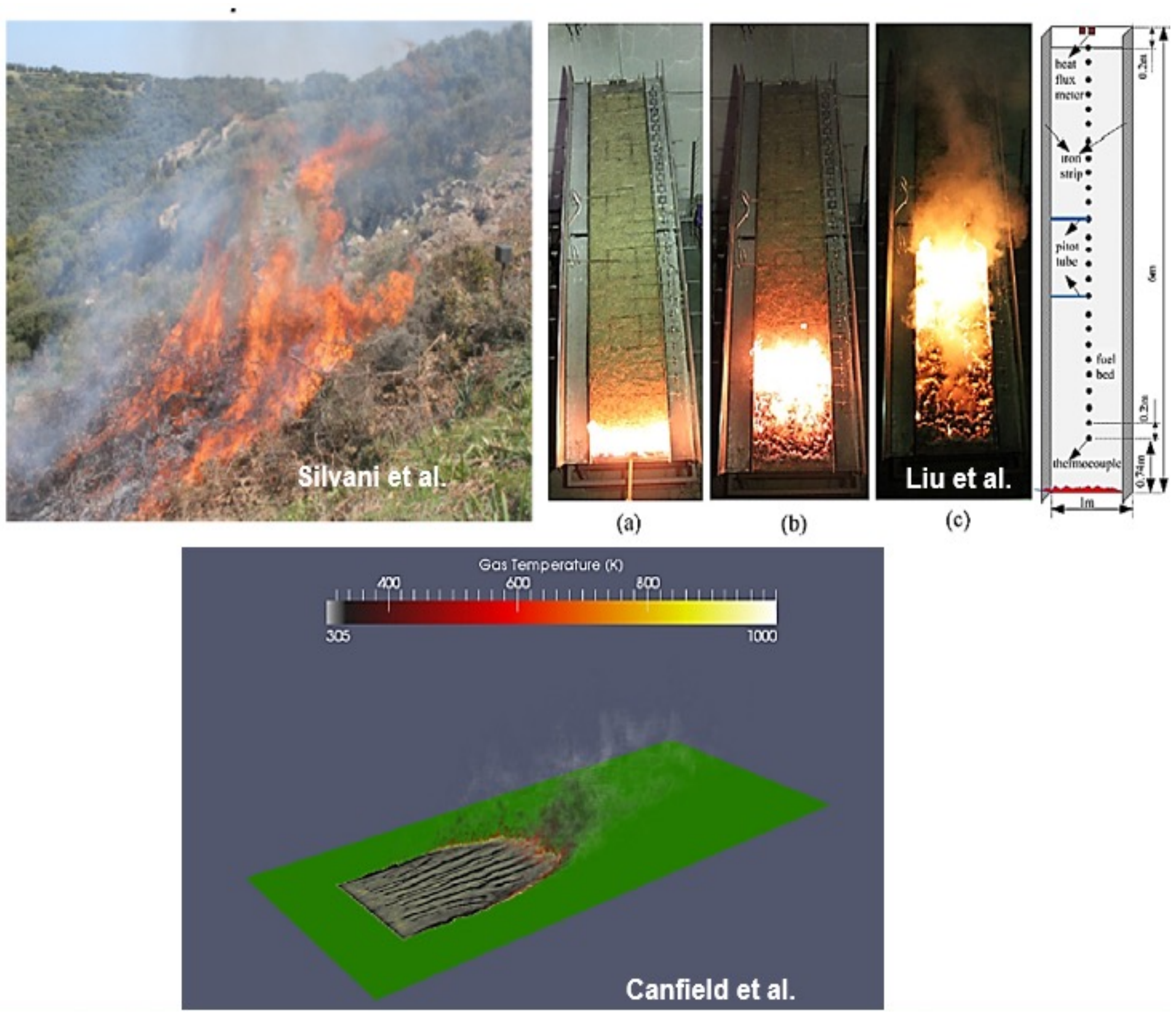
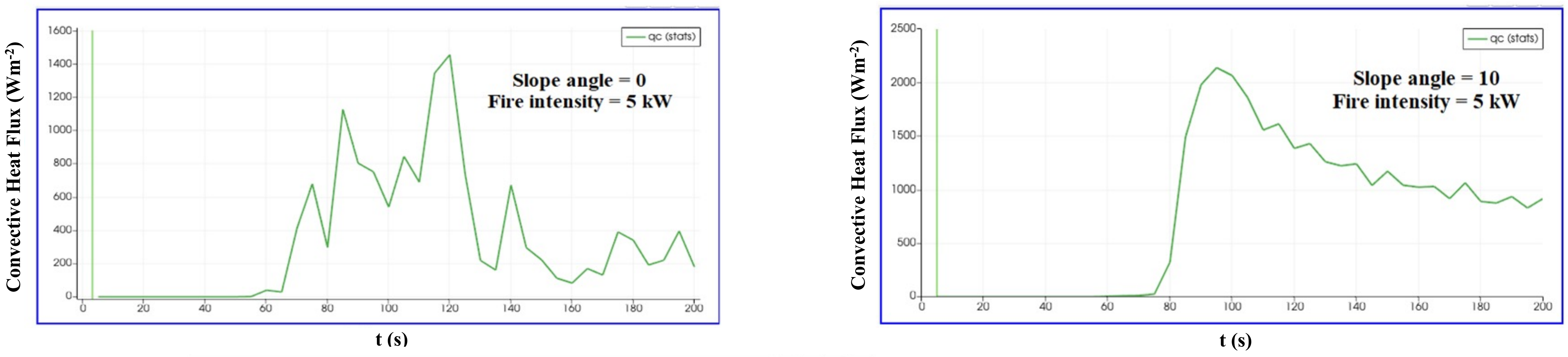


***Fig. 1**: Experiments and simulations involving fires propagating upslope.*

Radiation and convection are the primary modes of heat transfer in bushfires. In this research, we use the FireFOAM platform to capture the convective heat flux (i.e., the heat carried by buoyant fire-heated air) from a simulated fire and compare it with output from existing numerical models such as Fire Dynamics Simulator. Of particular interest is the role that convective heating plays in fires travelling upslope (see Figure 1).

The proposed numerical approach will enhance our understanding of convective heat transfer during fire propagation, ultimately contributing to better models that underpin more effective fire management and mitigation strategies.

Figure 2 shows the convective heat flux associated with fires travelling on flat ground, up a slope of 10° and up a slope of 20°. Future work will simulate the added influences of wind speed, fuel type and size and fuel packing ratio on convective heating and cooling.



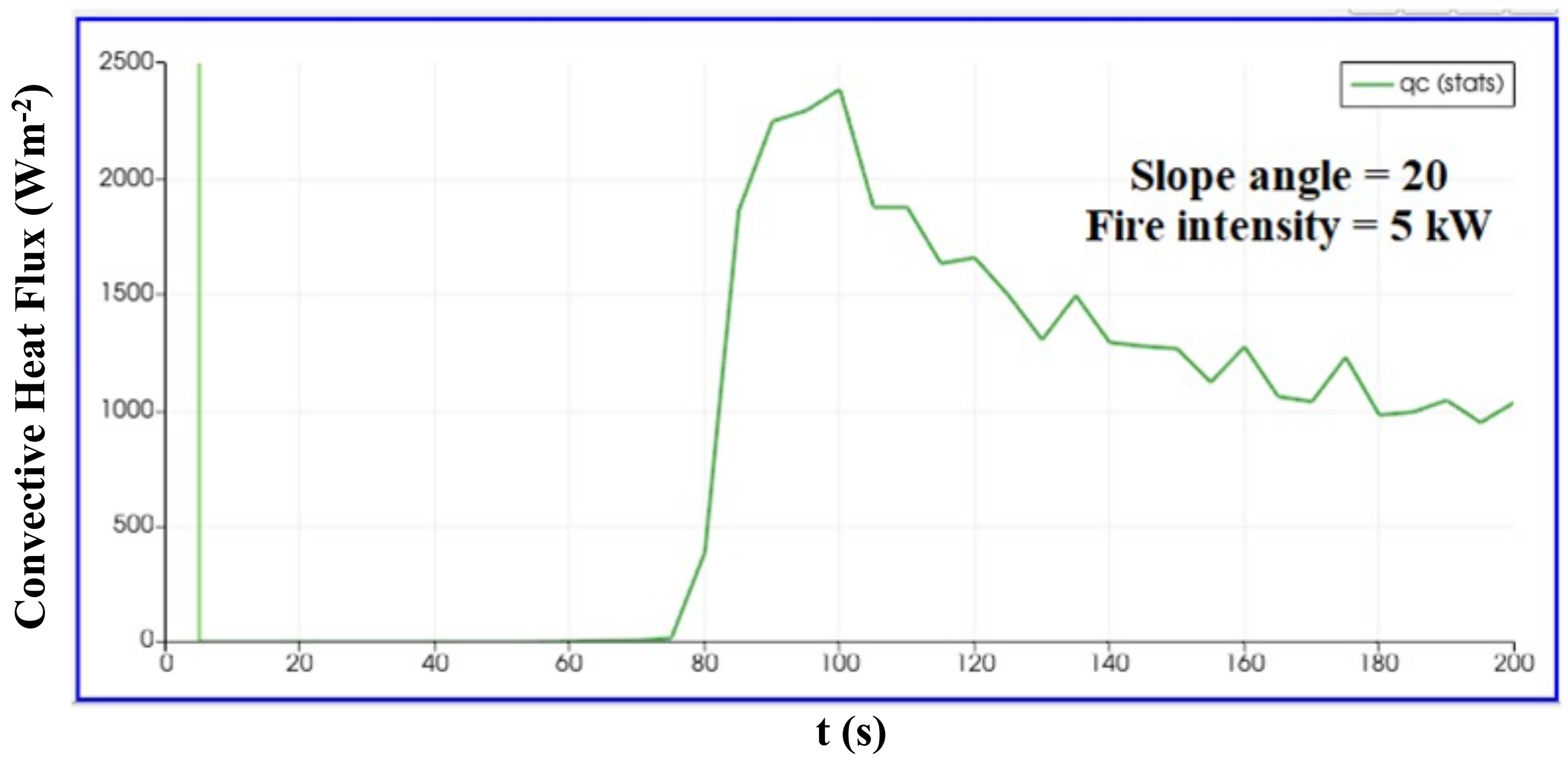


***Fig. 2**: Simulation results for fires burning on inclined terrain. Fires burning upslope (top right and bottom) produced sustained convective heat fluxes that are not seen for fires burning on flat ground (top left).*

Project Supervisor:
A/Prof. Harald Kleine
UNSW Canberra

For more information contact:
Mohamad Sadeghi, Maryam Ghodrat or Harald Kleine
<bushfire.research@unsw.edu.au>

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Physics-based wildfire simulation

Bushfires are difficult to study experimentally due to the inherent dangers that they pose. Simulation of wildfires using physics-based models offers an alternative approach, where fire behaviour can be safely studied using established computational techniques.

In physics-based modelling, equations governing the fluid flow, the combustion of gases, and the thermal degradation of solid fuels are solved using numerical methods.

- This provides the most faithful simulations of fire spread possible
- The problem is computationally difficult: thousands of CPU hours on supercomputers!
- Provides insight into heat transfer mechanisms, which drive the fire and are difficult to measure experimentally

Physics-based simulation is widely applicable to different fire scenarios. It is capable of reproducing observations made in the field and the laboratory. Figure 1 demonstrates a variety of fire scenarios that we have studied with physics-based wildfire simulation.

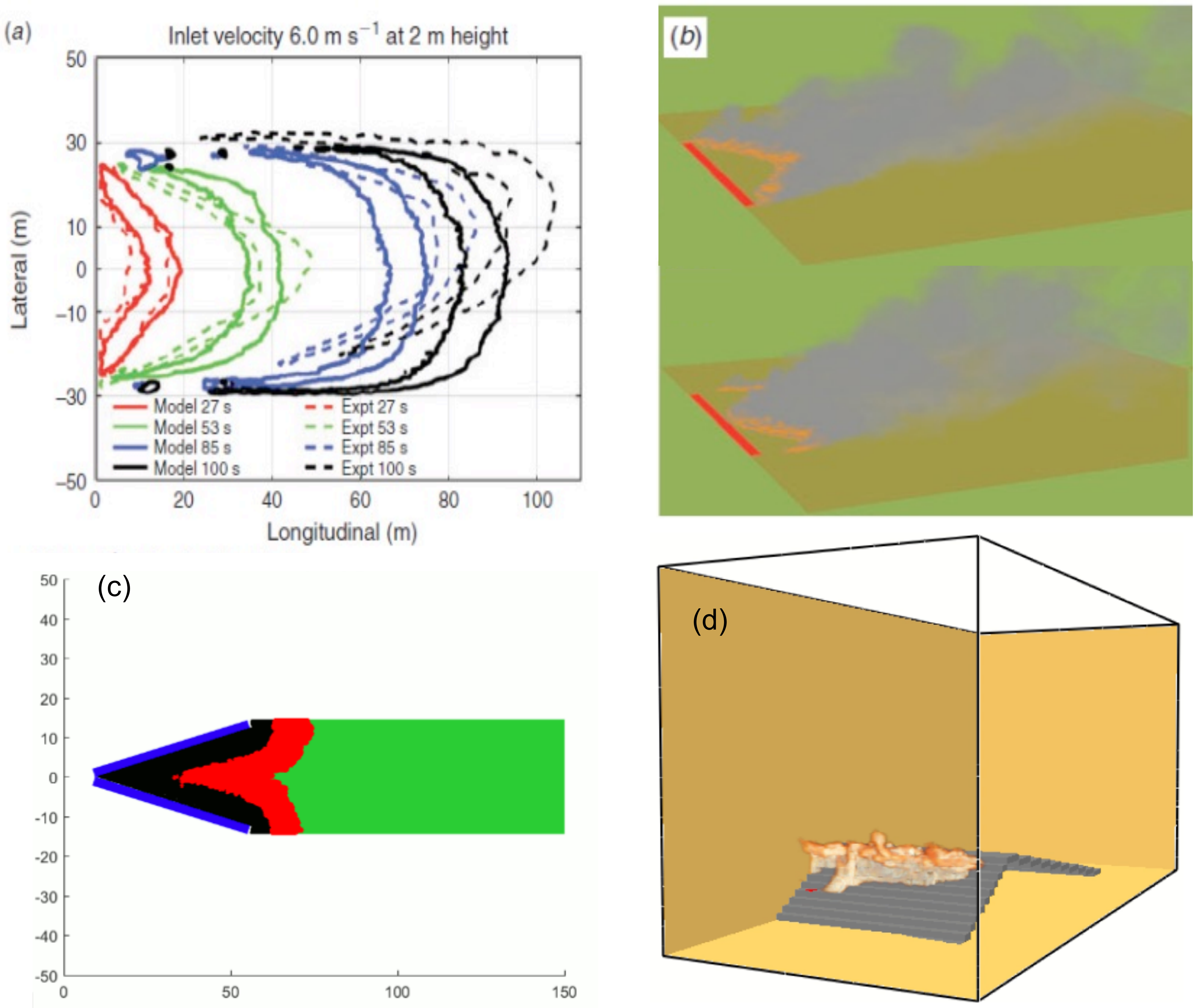

Fig 1: (a) comparing physics-based simulations to experimental results shows that similar spread rates and fire shapes can be obtained.

(b) Investigating different ignition patterns reveals dynamic fire behavior that is ignored in empirical models.

(c) Fire merger simulations shows jumps in intensity and spread rate.

(d) Simulations of laboratory experiments of Vorticity-driven Lateral Spread, a complex dynamical phenomenon, can be reproduced.

Similar physics-based models are currently being applied to ember storms, to faithfully reproduce the motion of embers from a forest, across the ground, and into built up wildland areas. We are working with government partners to use these simulation results to help design suburbs that will be more resilient to future bushfire threats.

Collaborators:
ACT Suburban Land Agency
Victoria University
University of Melbourne

For more information contact:
Duncan Sutherland or Jason Sharples
<bushfire.research@unsw.edu.au>

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