

**23rd International Conference on
Harmonisation within Atmospheric Dispersion Modelling
for Regulatory Purposes
15-19 September 2025, Hamburg, Germany**

EXTENDED ABSTRACT

Abstract title: *MODISAFE – Experimental Study of Urban Dispersion of Buoyant Gasses*

Name and Affiliation of the First Author: Charles Deebank¹

Email of first author: cd00749@surrey.ac.uk

Names and Affiliations of the Co-authors: Paul Hayden¹, Alan Robins¹, Thomas Vik², Marco Placidi¹, Matteo Carpentieri¹

1: EnFlo Laboratory, School of Engineering, University of Surrey (UoS)

2: Forsvarets forskningsinstitut (FFI)

Introduction

MODISAFE is a multinational research project, aimed at improving the knowledge and representation of source conditions, loss processes and agent fate in Chemical, Biological, Radiological and Nuclear (CBRN) threat modelling. A project overview is provided in the accompanying abstract from this conference (Cruse, 2025). This abstract outlines a series of experiments carried out under MODISAFE WP32, which examined dispersion effects from non-passive sources in urban boundary layers, generating a dataset that can be used for model development and validation exercises.

Fires are a particularly common vector for the spread of hazardous materials within urban environments, yet there is a notable shortage of field or experimental data concerning dispersion from thermally hot sources in highly turbulent flows. The majority of existing work on dispersion of hot (or lighter than air) pollutants focuses on industrial emissions from elevated stacks – in other words elevated sources out of the roughness sublayer region. This case is relatively well understood and partly as a result of its simplicity, analytical models have proved largely sufficient for modelling purposes. In comparison, most fires arise from what are effectively ground level sources. In an urban environment, this means that the release will occur in a highly turbulent flow field, with many obstacles and resulting obstacle-driven flows. Given the advances in modelling capabilities, it is desirable to expand experiments to this domain, both to better understand the role of buoyancy in these urban dispersion problems from a fundamental perspective and to provide a validation dataset for continued model development. This dataset will be made publicly available following the conclusion of the project and we would encourage the wider HARMO community to utilise it to this end.

Experimental Setup

This experiment was carried out in the EnFlo wind tunnel at the University of Surrey, a suck-down atmospheric wind tunnel with a working section of 20m x 3.5m x 1.5m (length x width x height). EnFlo specialises in simulating stratified atmospheric flows, either in

**23rd International Conference on
Harmonisation within Atmospheric Dispersion Modelling
for Regulatory Purposes
15-19 September 2025, Hamburg, Germany**

terms of a thermally stratified boundary layer – or as in this case – dispersion of heavier-and-lighter than air pollutants. All tunnel systems, including data collection are autonomously controlled, enabling overnight and unsupervised running.

To provide a representative urban boundary layer, a simplified model of Oslo city centre was developed by UoS and FFI. At full scale, it represents a 1 x 2 km² section of the city or 6.6 x 3 m² in laboratory scale (1:300) for the wind tunnel experiments. It is of a ‘street network’ type where city blocks are modelled as single objects and features ~250 buildings with heights between 16.5 and 200 mm at wind tunnel scale. Two sources are located within the model: source A is located at a four-way intersection between two street and source B is located in the wake region of a tall building (figure 1). These are both 50 mm diameter point sources located on the tunnel floor and pointing directly upwards. Upstream of the model, Irwin spires at the tunnel entrance and an 11 m fetch of rectangular floor roughness elements were used to generate a representative urban boundary layer as model inflow conditions.

Simultaneous velocity and concentration measurements are taken via a spatially co-located 3D Laser-Doppler Anemometer (LDA) and Fast-response Flame Ionisation Detector (FFID). These instruments are mounted on an automated 3-axis traverse, enabling over 300 points to be taken across the model, per case. To facilitate the measurement of turbulent mass fluxes the LDA and FFID are synchronised through a dynamic calibration process.

The primary objective of this experiment – creating a validation dataset for model development in conjunction with a series of LES and RANS simulations – has driven its design, particularly in terms of measurement plans. Release conditions were selected to provide a wide range of dispersion behaviours, based on the work of Robins (1994). In the case of lighter-than-air (LTA) releases, release flow rate and density were prescribed so that both lifted plumes and intermediate cases where buoyancy effects modify dispersion but do not lead to a lifted plume, were present. Heavier-than-air (HTA) cases were also included.

Concentration measurements were organised into a series of three planes taking a lateral cross-section of the plume above building height and six vertical profiles down to street-level. This provides insight into both large-scale plume behaviour and local effects below canopy height. Alongside these measurements, a series of LDA measurements studying the internal boundary layer growth over the model and incoming boundary layer upstream of the model are provided in the dataset.

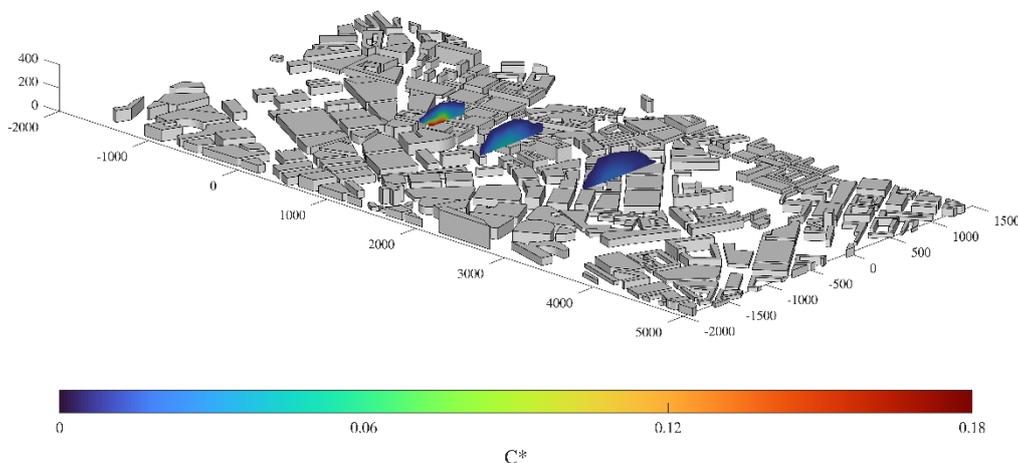
23rd International Conference on
Harmonisation within Atmospheric Dispersion Modelling
for Regulatory Purposes
15-19 September 2025, Hamburg, Germany



Figure 1: MODISAFE Oslo Model. Building colour denotes height. Source location A is denoted by a red circle, lateral measurement planes by black lines and vertical profiles by red squares.

Preliminary results

For brevity, a subset of results from source A will be discussed herein to illustrate some of the complex plume behaviours observed. Figures 2 to 4 show interpolated planar sections of the plume for three different source conditions: neutrally buoyant, as well as the most extreme LTA and HTA cases, in figures 2, 3, and 4, respectively. In the neutral case, the centreline of the plume is deflected ~ 300 mm in the y -direction, but otherwise disperses as would be expected for a passive release. The LTA release shows more complex dynamics. A large portion of the plume is lifted off the ground and not deflected along the y -axis, while some of the plume is still transported laterally. Analysis of mass fluxes and flow-visualisation studies (omitted here) show that the majority of scalar transport occurs within the lifted portion of the plume in this case, i.e. the portion remaining close to the ground is likely ‘trapped’ to some extent in a re-circulation region behind one of the large buildings. In the far field, the LTA plume is still clearly lifted off the model floor.



**23rd International Conference on
Harmonisation within Atmospheric Dispersion Modelling
for Regulatory Purposes
15-19 September 2025, Hamburg, Germany**

Figure 2: Planar concentration data from passive release

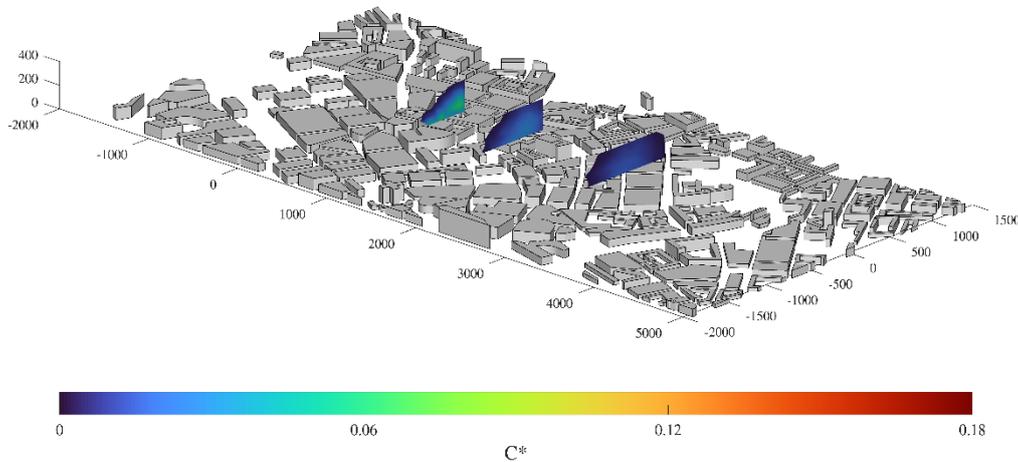


Figure 3: Planar concentration data from lighter-than-air release

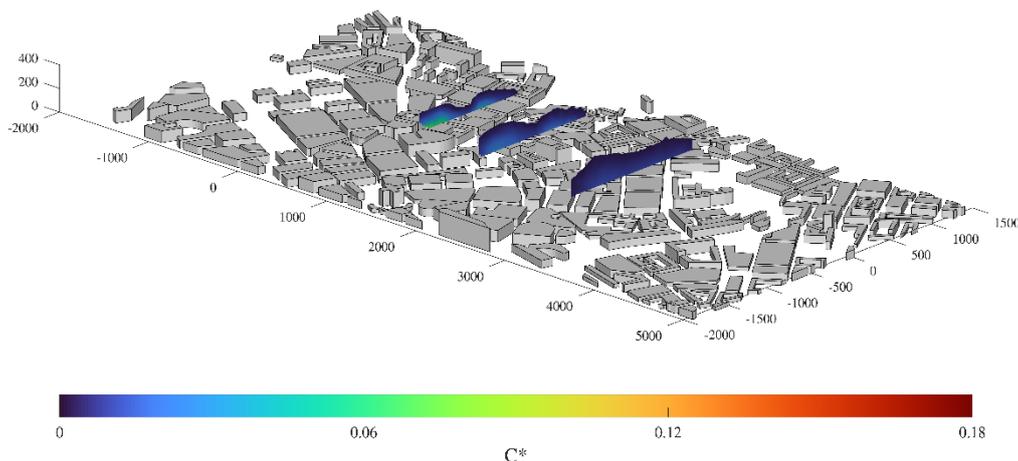


Figure 4: Planar concentration data from heavier-than-air release

The HTA case shows the most obvious difference from the neutral cases. At all three measurement locations, the plume is bifurcated – it has two distinct peaks in concentration – as if dispersing from two separate sources, alongside the expected increase in lateral spreading. The large differences seen between the different density cases are attributed to the complex geometry around the source region, and its interaction with buoyancy driven flows. Figure 5 shows the primary transport phenomena associated with these dispersion patterns, derived from the above concentration measurements and flow-visualisation experiments. For the passive case (red lines), dispersion is dominated by advection down the larger street canyon with the plume remaining trapped inside this canyon before dispersing around the tall buildings at the canyon end. In the case of the LTA release (blue line), the upwards momentum and buoyancy can dominate over the canyon flow and enable the plume to intermittently escape the street canyon. With the HTA release

**23rd International Conference on
Harmonisation within Atmospheric Dispersion Modelling
for Regulatory Purposes**
15-19 September 2025, Hamburg, Germany

(purple line), upwind spreading due to gravity currents enables the plume to spread down a small side street before dispersing at its exit. This gives the appearance in the far-field of two separate sources.

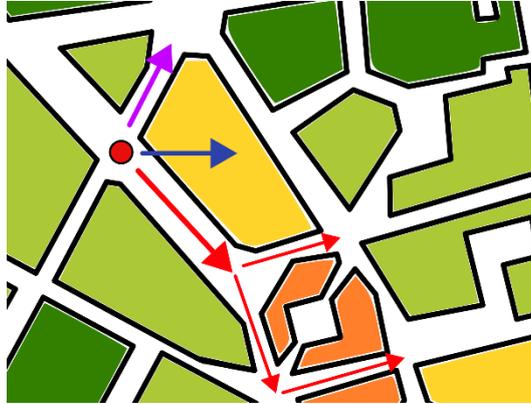


Figure 5: Dispersion pathways from source A: passive dispersion pathway in red, additional pathways for HTA and LTA releases in purple and blue, respectively

Conclusion

MODISAFE WP 32 has successfully simulated a wide range of non-passive dispersion scenarios within a complex urban geometry. A detailed model of Oslo city centre has been designed, manufactured and tested in the EnFlo tunnel as well as successfully used as geometry for computer modelling (not discussed herein). A wide range of plume behaviours have been re-created within the model, providing a comprehensive dataset for model comparison which will be made publicly available after the conclusion of the project. The results demonstrate the importance of appropriately modelling the near-source region, due to the very powerful impact of near source effects, particularly the interaction between buoyancy and obstacle driven flows.

References

Cruse et al. (2025) *MODISAFE – Project Overview* HARMO23, Hamburg

A.G. Robins. “Flow and dispersion around buildings in light wind conditions”. In: 4th IMA Conference on Stratified Flows. University of Surrey: Oxford University Press, 1994.