SHOULD DISPERSION MODELS STOP PRETENDING BUILDINGS DON’T EXIST?

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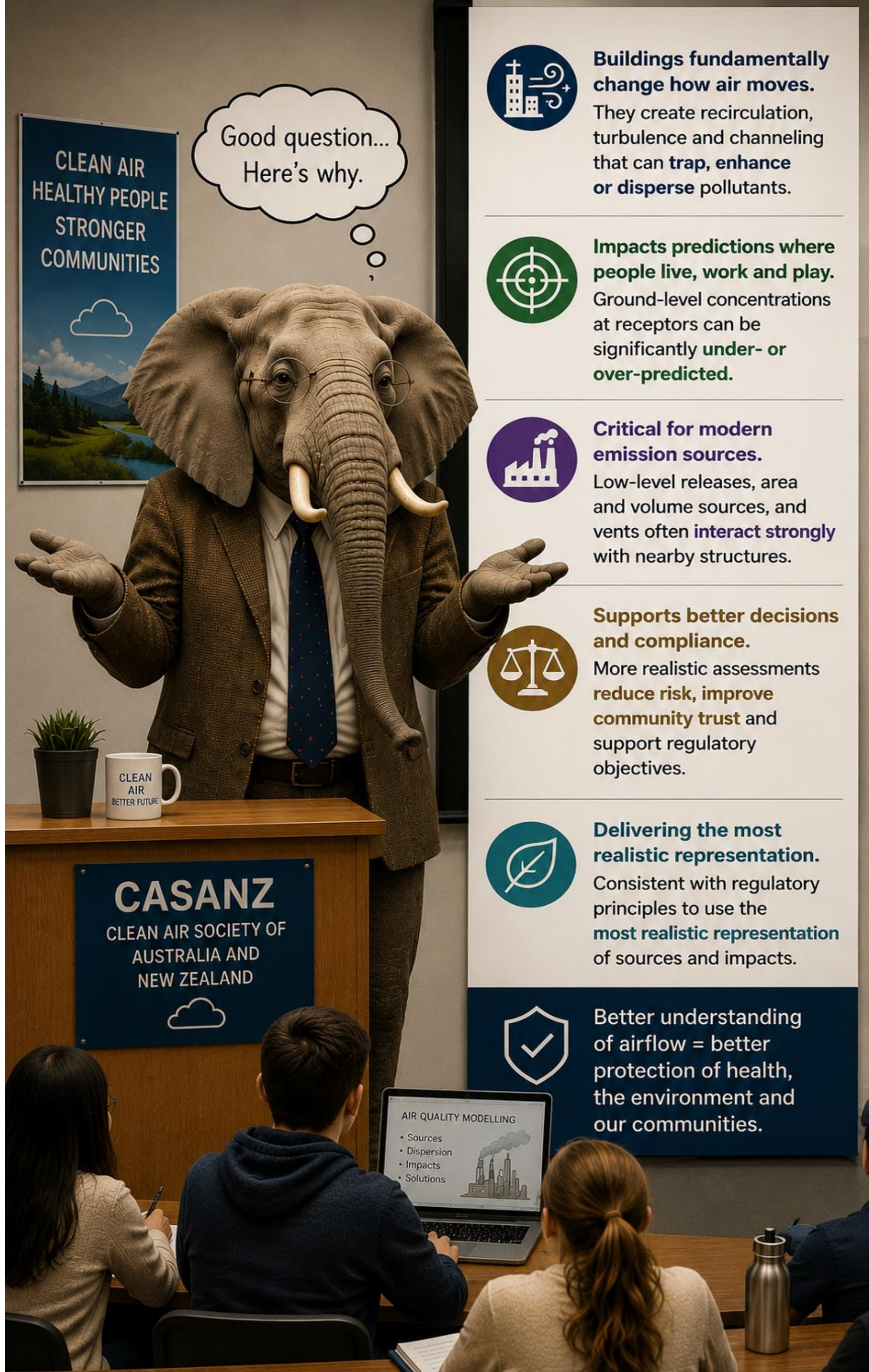
Presentation Overview

- **Why the consideration of complex environment airflow modelling matters.**
- **Study approach.**
- **Case study results discussion.**
- **What the model comparison tells us.**
- **Implications & conclusions.**



Why consideration of complex airflow modelling matters…

- Urban and industrial sites are becoming more geometrically complex.
- Buildings create turbulence, wakes, recirculation and channelling that can control near-field dispersion.
- AERMOD and CALPUFF use simplified building-wake treatments. Building effects are generally not represented for area or volume sources or buildings located away from the source.
- Regulatory guidance is moving toward realistic representations of emissions and impacts.

Reference: 7 News 2026

Study Design

AERMOD	CALPUFF	GRAL
Regulatory Gaussian model Simplified building wake treatment	Regulatory puff model Simplified building wake treatment	Advanced complex environment model Explicit building-induced airflow

A comparative exercise - not a formal model validation

- Three different air pollution scenarios assessed using three different dispersion models.
- Same building geometries used across models.
- One year of similar meteorology (same year), processed using model-specific best-practice approaches (acknowledging that different met processors produce slightly different meteorology).
- AERMOD/CALPUFF used fine scale regulatory-scale grids; GRAL used a 2 m horizontal grid.
- Comparison focuses on plume shape, spatial variability and interaction with complex buildings and whether the model produces a realistic representation of the plume.

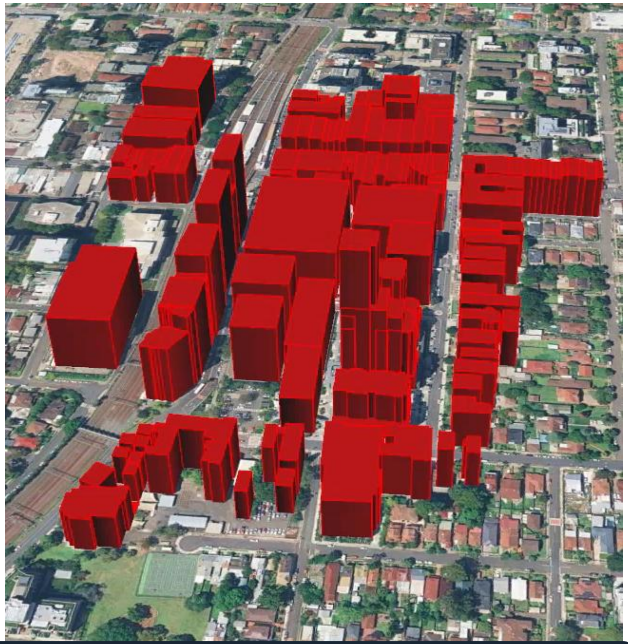
Three deliberately complex, but not unusual AQ scenarios

1 Airport terminal

Low-level area sources
Large terminal structures

2 Inner-city data centre

13 elevated stacks
Dense high-rise setting



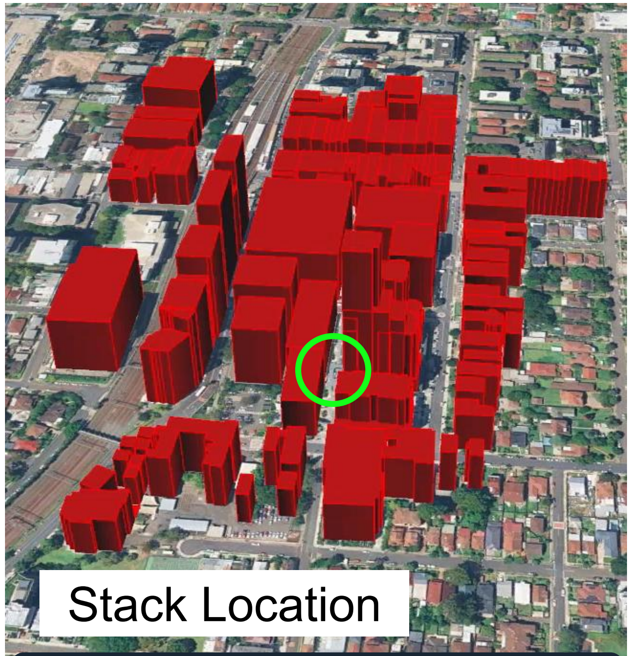
3 Sewer vent

Low-level point source
Urban canyon

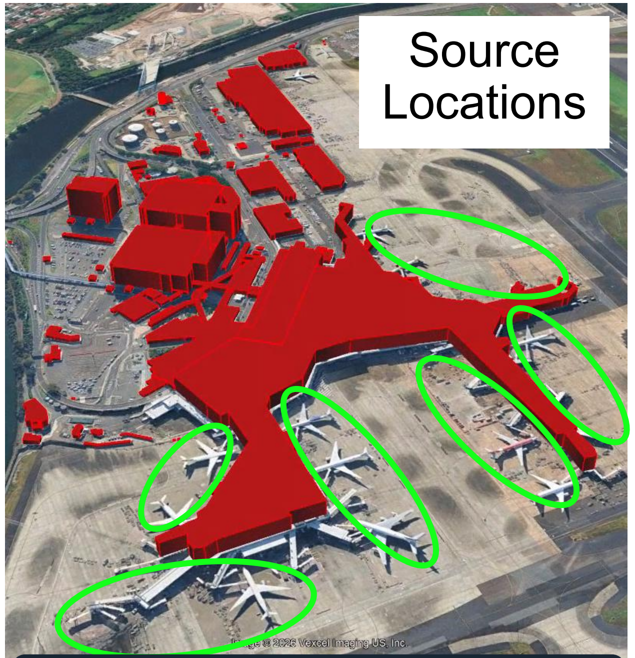
Increasing flow complexity

The scenarios span area-source dispersion, elevated stack downwash and a highly constrained urban-canyon environment.

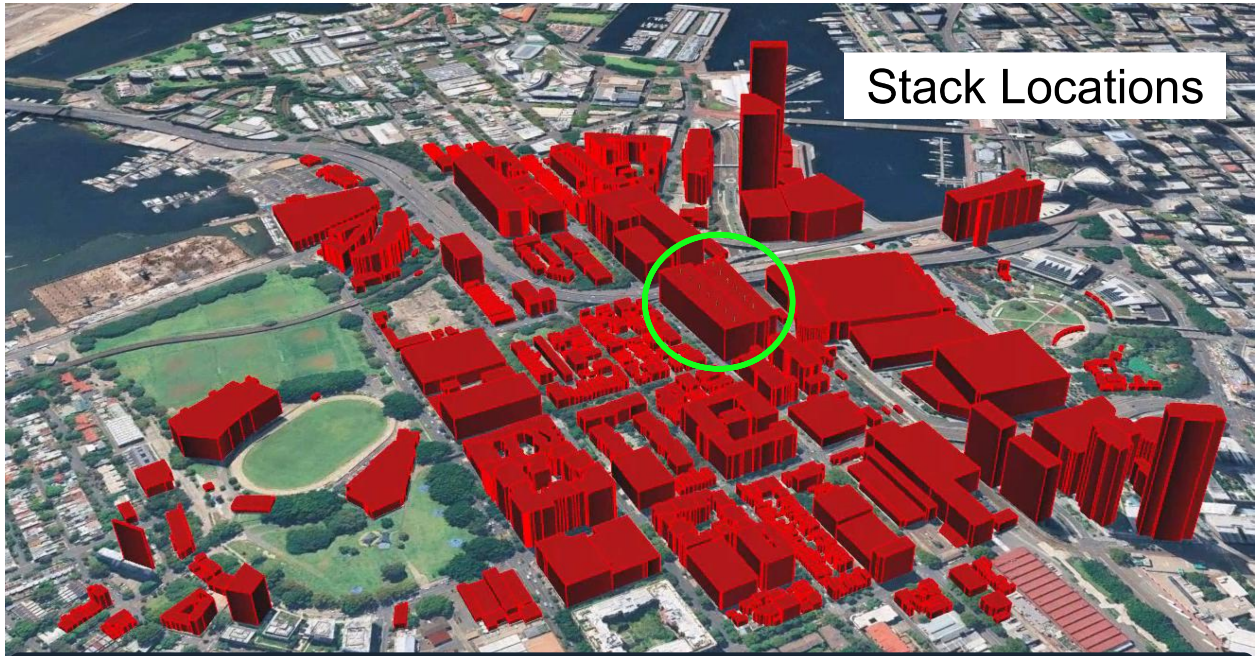
Sources included in the modelling



Sewer vent / urban canyon



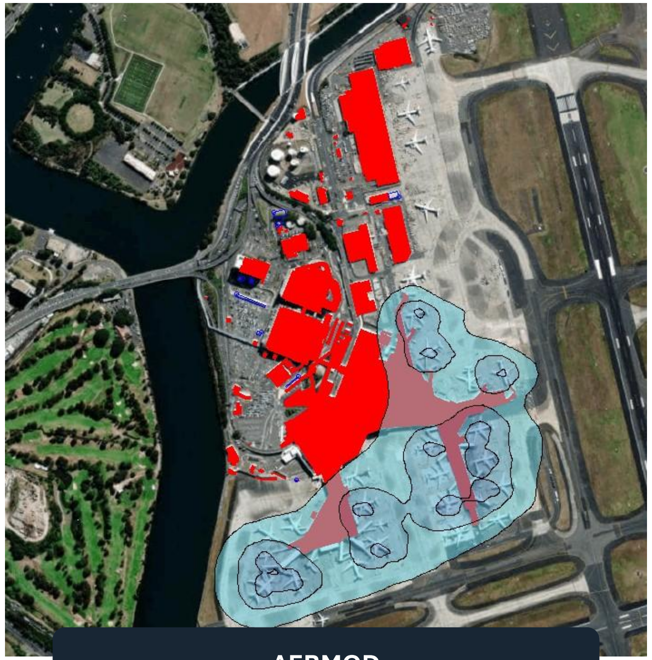
Airport terminal



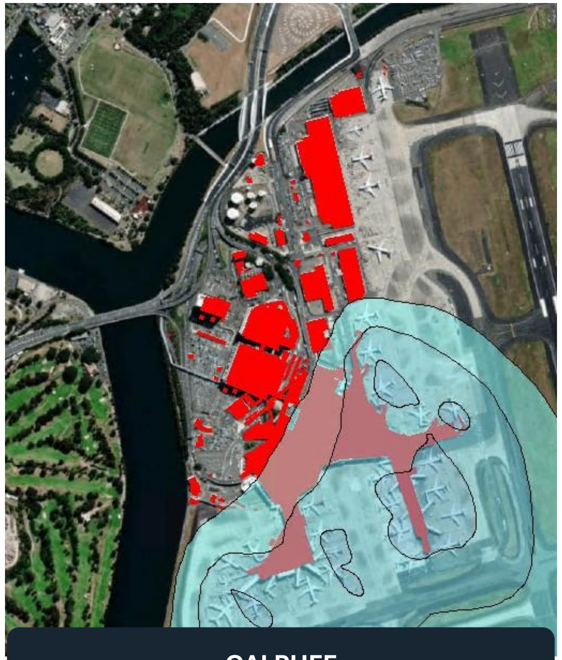
Inner-city data centre

Why this matters: closely spaced and varied-height structures create the recirculation, wake and channelling effects that are central to the model comparison.

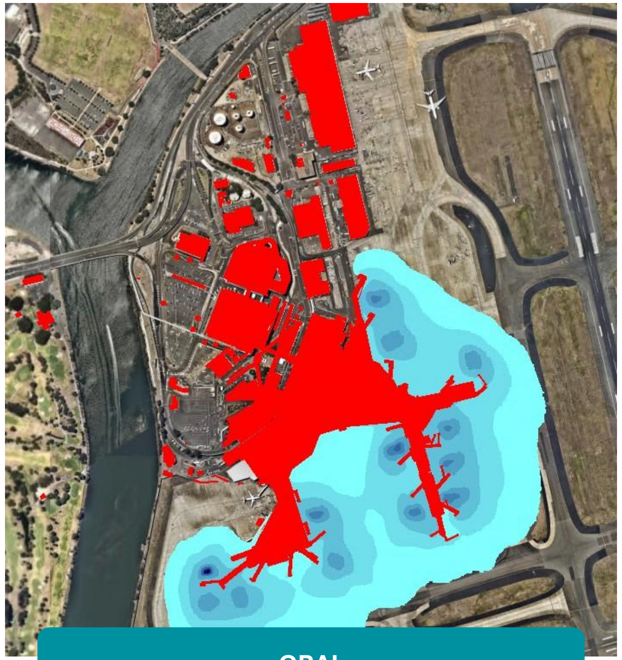
Airport terminal – ground level concentrations, area sources



AERMOD



CALPUFF



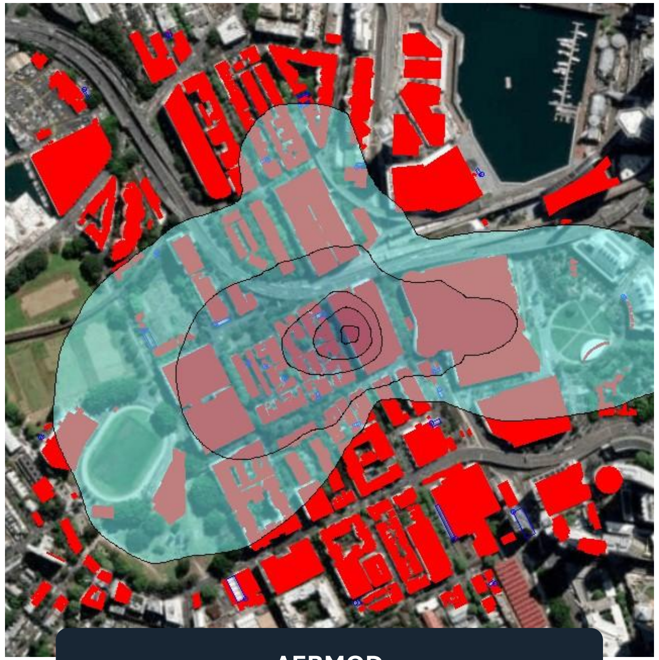
GRAL

AERMOD
Smooth, broadly symmetrical plume patterns dispersing through buildings.

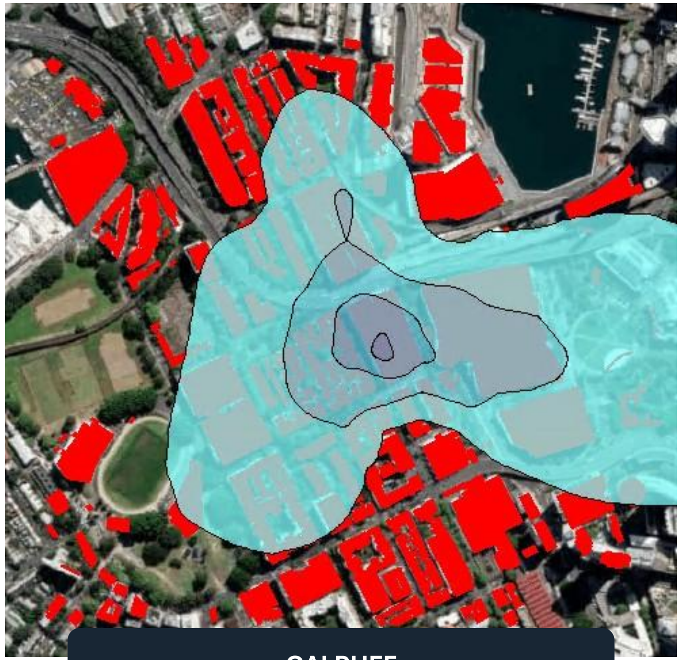
CALPUFF
Slightly more lateral spread; same dispersion through buildings.

GRAL
Channelling, sheltered hotspots and less dispersion near structures.

Inner-city data centre – ground level concentrations, elevated stacks



AERMOD



CALPUFF

GRAL

AERMOD
Conventional downwind plume with moderate downwash.

CALPUFF
Broadly similar to AERMOD; fine-scale wakes not resolved.

GRAL
Plume redirection, entrapment and local accumulation zones.

A test of stack releases embedded within a dense high-rise environment

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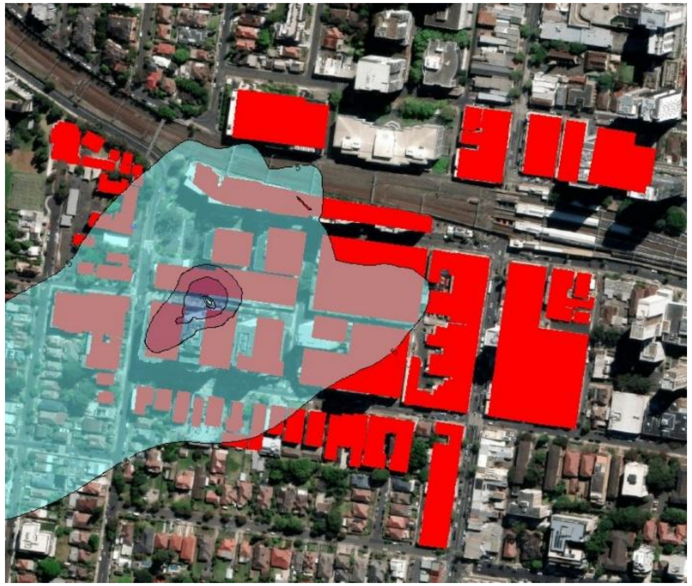
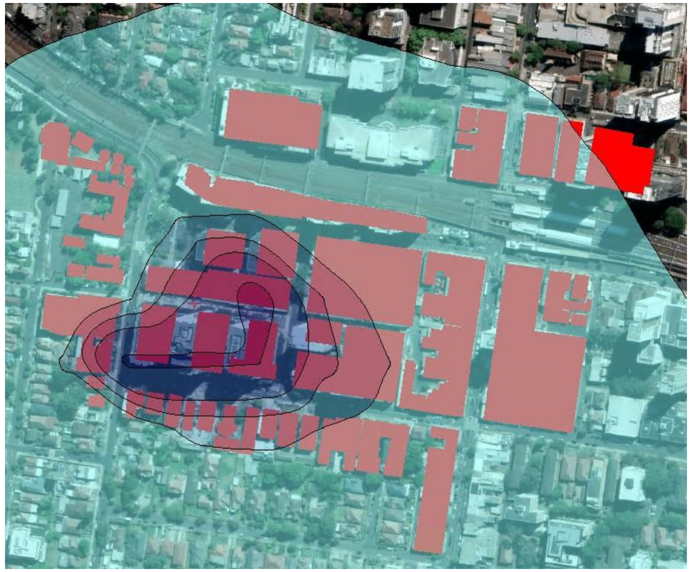
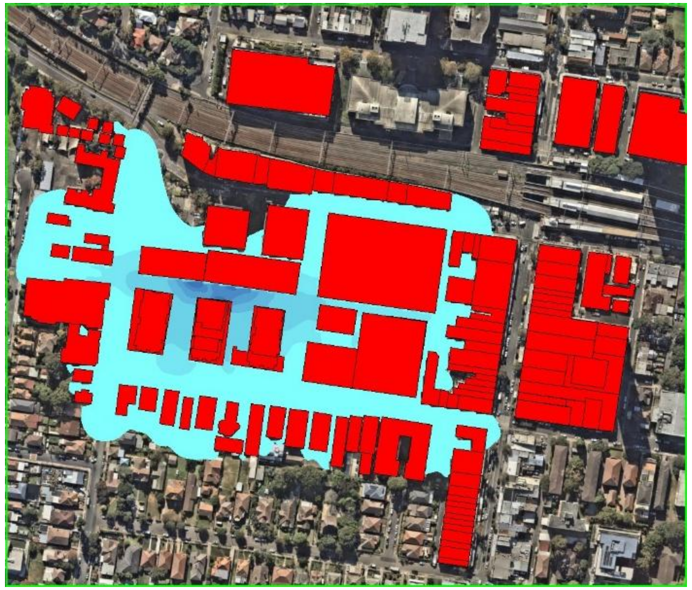
Sewer vent – ground level concentrations, low level stack



AERMOD



CALPUFF



GRAL

AERMOD
Narrow plume; canyon effects not explicitly resolved.

CALPUFF
Greater lateral spread close to source, then uniform.

GRAL
Strong confinement, recirculation and secondary peaks.

What changed when buildings were explicitly resolved?

AERMOD / CALPUFF: smoother, more diffuse fields → GRAL: building-driven, spatially heterogeneous fields

1 Plume shape

Smooth Gaussian-style concentration gradients became structured plumes shaped by wakes, recirculation and flow around buildings.

2 Channelling

Street corridors and gaps between buildings redirected plume transport, producing elongated impact zones not evident in the regulatory-model outputs.

3 Local accumulation

Sheltered areas, leeward façades and courtyards developed localised concentration enhancements and secondary peaks.

4 Near-field variability

Concentration gradients became much more spatially variable, with the largest model differences close to sources and within dense building clusters.

How this appeared in the three scenarios

Airport terminal - area sources

GRAL showed flow channelling between terminal buildings, sheltered operational-area hotspots and noticeably lower dispersion in areas affected by structures.

Data centre - elevated stacks

The plume was redirected along street corridors, with potential entrapment between buildings and accumulation on leeward sides and within courtyards.

Sewer vent - urban canyon

Building confinement produced strong street-canyon transport, recirculation at intersections and secondary concentration peaks.

Key implication: as urban density increases and sources move closer to buildings, model choice increasingly affects where impacts are predicted - not just the magnitude of the peak.
Plume concentrations can be counterintuitive using different models where plumes disperse through buildings

Implications for model selection

Regulatory models remain suitable for specific applications

- More open environments
- Adequate separation between sources, complex geometry and receptors
- Building-scale flow is unlikely to dominate the impact
- Assessment is focused on broader plume transport rather than microscale near-field gradients

Triggers to consider for explicit building resolution

- Low-level releases close to structures
- Dense or closely spaced buildings
- Street canyons, courtyards or sheltered areas
- Receptors located within the near field
- Likely wake, recirculation or channeling effects
- Area / volume sources where conventional building treatment is limited

The model-selection question

Critical question to ask is

"Is the model capable of representing the physical processes that are likely to control dispersion at the receptors of interest?"

Where buildings materially affect airflow, explicit resolution may provide the more realistic representation.

An example decision pathway may be as follows:

1 Source
Height, type and proximity to buildings

→

2 Geometry
Density, height variation, urban canyons / wakes

→

3 Receptors
Near-field location and required spatial resolution

→

4 Model
Select the approach that represents governing physics

Important regulatory note

Where complex building-induced flows dominate, agreement with a simplified Gaussian model should not be treated as the test of an advanced model's validity. Fundamental differences in model formulation mean agreement may be neither expected nor evidence of better performance.

Elephant in the room….

- Is it a surprise that using a model that explicitly considers air flow provides different plume shapes?
- Of course, answer is no, so why was this study undertaken?
- Undertake a study explicitly showing that what is expected to occur is what is occurring and whether there are any other effects that were unexpected.
- Provide a starting point for discussions around the adoption of models that more effectively consider complex environments.
- This study is a means to an end not the end itself…lots more work needed on understanding these models and the circumstances in which they should be used in preference to traditional models.

Reference: ChatGPT 2026
(In case that wasn't obvious☺)

So which model is right?

- Short answer is none of them are right.
- They each provide a different representation of air pollution predictions within the limitations inherent to each model.
- Aim is to identify which model is best for each modelling circumstance and work within known (and possibly agreed) settings that produce results that are plausible and reliable.
- As discussed, two factors that should be used to define which model should be used include:
    - Complexity of the built environment close to the source (using common wake relationships to establish possible wake influences).
    - Proximity and complexity of receiving environment, particularly the area commonly affected by wakes (5-15 stack heights from sources).

Reference: ChatGPT 2026
(In case that wasn't obvious☺)

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Take-home messages

1. Buildings can materially change plume behaviour.
2. The largest differences occur in complex, near-field environments.
3. AERMOD and CALPUFF remain useful – but their simplifications matter.
4. GRAL can represent channelling, recirculation and local hotspots.
5. Modelling with CALPUFF and AERMOD as a comparison to GRAL is of limited value
5. Next step: clearer guidance is needed on when explicit airflow should be considered when choosing a model for an AQIA.

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Thank you

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