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BRE CENTRE *for* FIRE SAFETY ENGINEERING

Approximate Travelling Distances of Water Mist Droplets in Tunnels

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Context

From PIARC "Road Tunnels: An Assessment of Fixed Fire Fighting Systems":

"In most cases, FFFS are not capable of extinguishing vehicle fires. The aims are to: slow down fire development, reduce or completely prevent fire from spreading to other vehicles, provide for safe evacuation, maintain tenability for fire-fighting operations, protect the tunnel structure and limit environmental pollution.
To fulfil these purposes, the FFFS must [amongst other things] be designed to handle air velocities in the range of 10 m/s that can result from ventilation system operation or natural effects..."

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Context

[to the best of my knowledge]

No water mist system in a tunnel has ever been tried under such ventilation conditions, let alone demonstrated to actually achieve any fire suppression.

So, what would happen if it was tried?

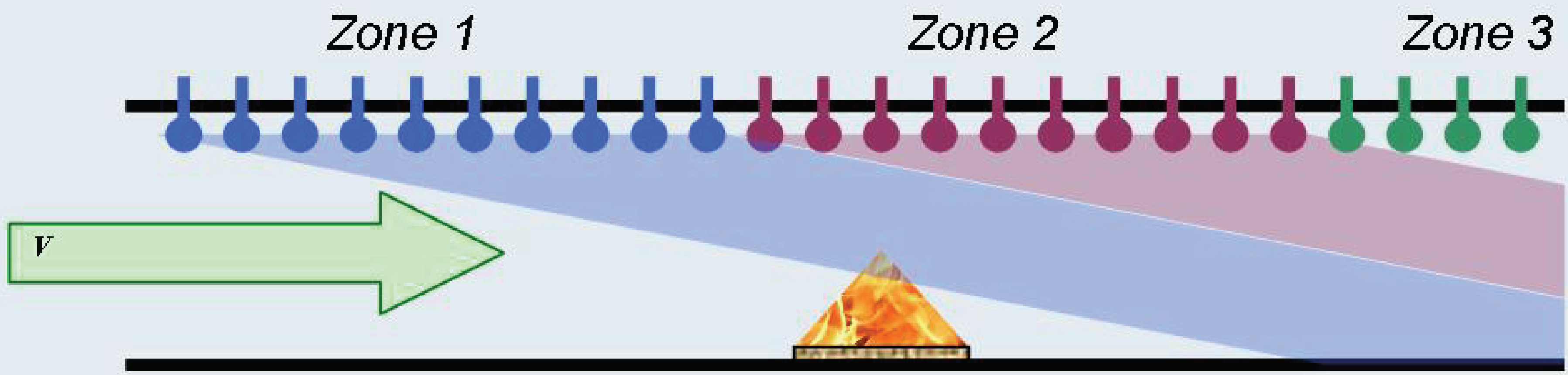
Where would the mist droplets go?

Overview

- Discussion of the problem
- Initial model description
- Initial model results (3rd ISTSS, Stockholm, 2008)
- Modifications to the model
- Modified model results
- Experimental ‘validation’ (for large droplets)
- CFD ‘validation’ (for small droplets)
- Future research
- Concluding comments

The problem

- Water mist droplets are tiny (~30-150μm)
  - good fire suppressing ability / like total flooding gas
  - smaller water supply (reservoir / pipes) requirements
  - but, very susceptible to ventilation
- The drops need to get to the fire!



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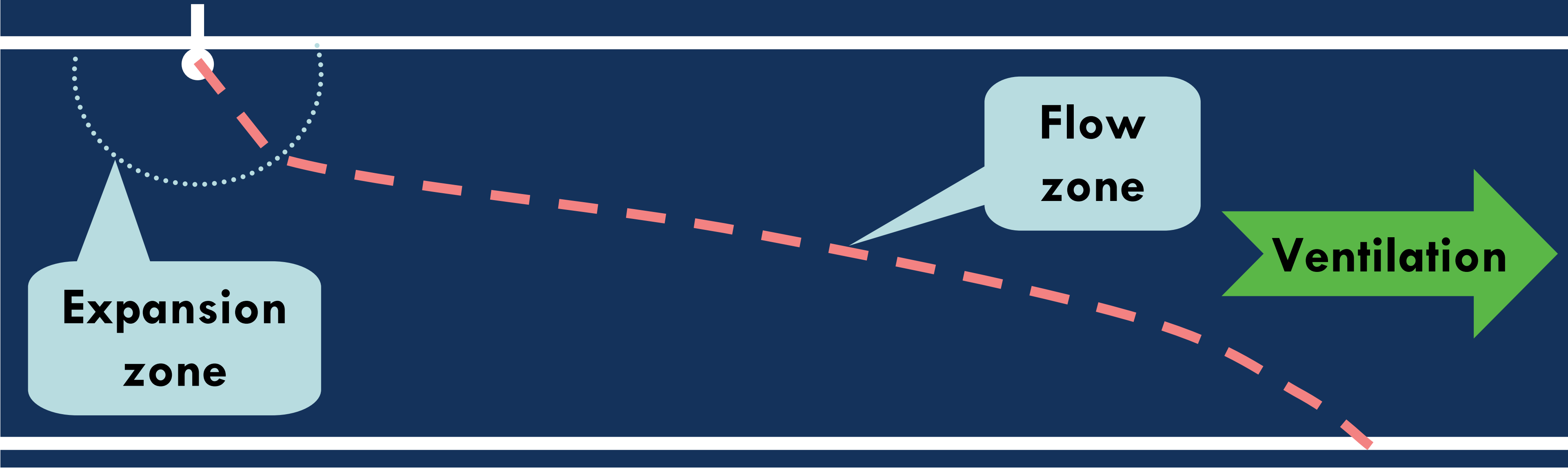
The original model

- Expansion zone:
  - droplet motion governed by exit velocity and initial angle of motion
- Flow zone:
  - droplet motion governed by longitudinal flow



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The original model

- Simple equations
- Laminar flow
- Isolated droplet
- Textbook drag coefficient
- No temperature effects

  (droplet does not evaporate)

Results presented in ISTSS Stockholm, 2008

$$\frac{d\vec{V}}{dt} = \vec{g} + \frac{1}{2} \cdot C_D \cdot \frac{\rho A_d}{m_d} \cdot \left|\vec{W}\right| \cdot \vec{W}$$

$$\vec{\mathrm{W}} = \vec{\mathrm{U}} - \vec{\mathrm{V}}$$

$$C_D = 0.4 + \frac{24}{\mathrm{Re}_w} + \frac{6}{1 + \sqrt{\mathrm{Re}_w}}$$

$$\mathrm{Re}_\mathrm{w} = \frac{\mathrm{d} \cdot \left|\vec{\mathrm{W}}\right|}{2 \cdot \nu}$$

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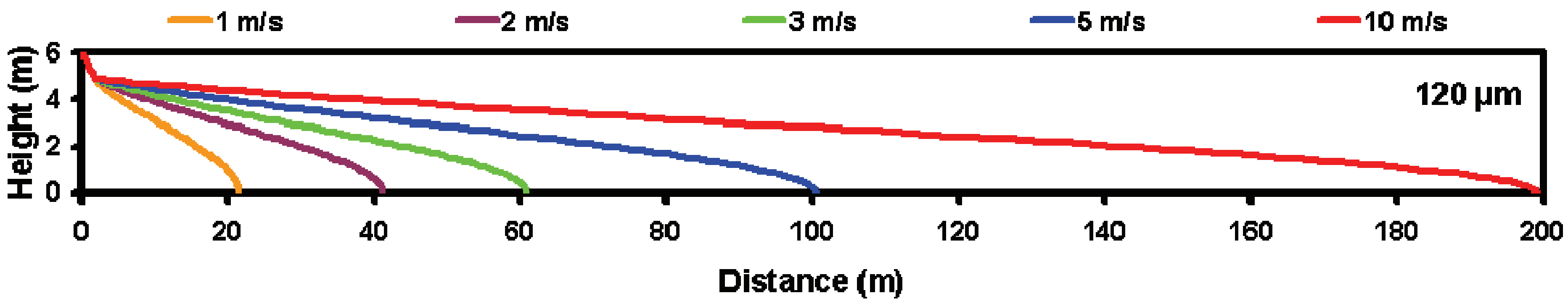
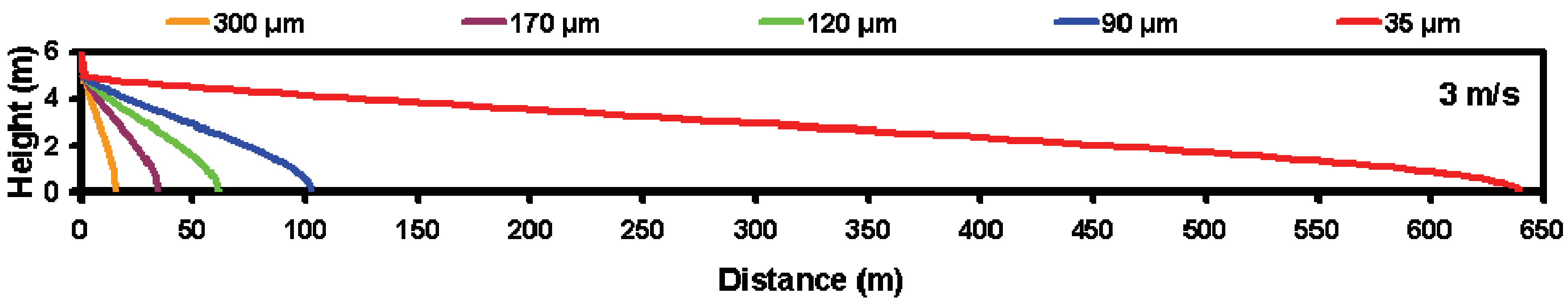
The original model (results)

- 120 µm droplets, various ventilation velocities:



- 3 m/s ventilation velocity, various droplet sizes:



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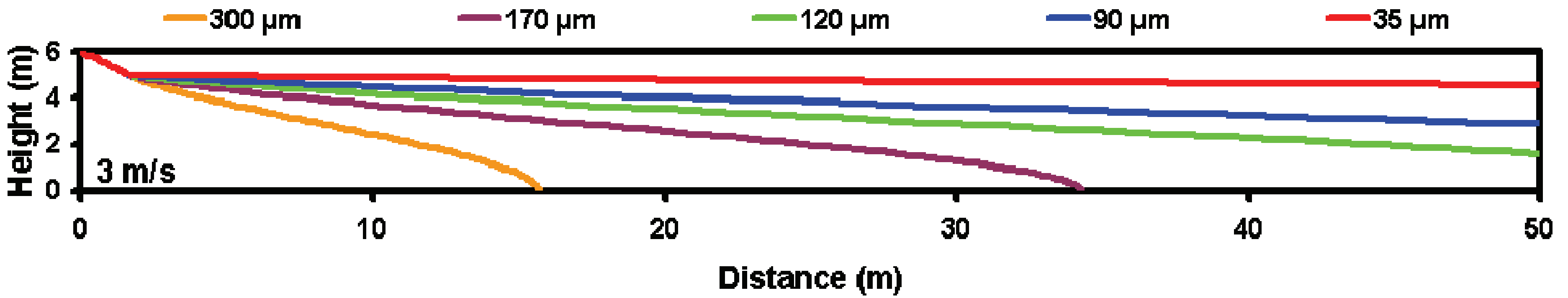
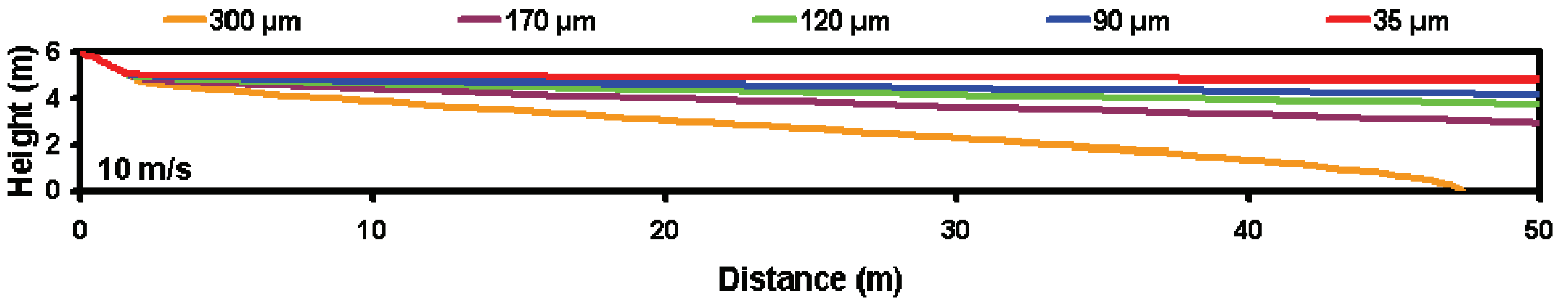
The original model (results)

- 50 m section of tunnel, 3 m/s velocity, various sizes:



- 50 m section of tunnel, 10 m/s velocity, various sizes:



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The modified model

- Variation of expansion cone parameters
- Introduction of turbulent flow
- Alternative drag coefficients

  (experimentally validated best fit coefficient used)
- 'Monte-Carlo' model
- Full details in the paper

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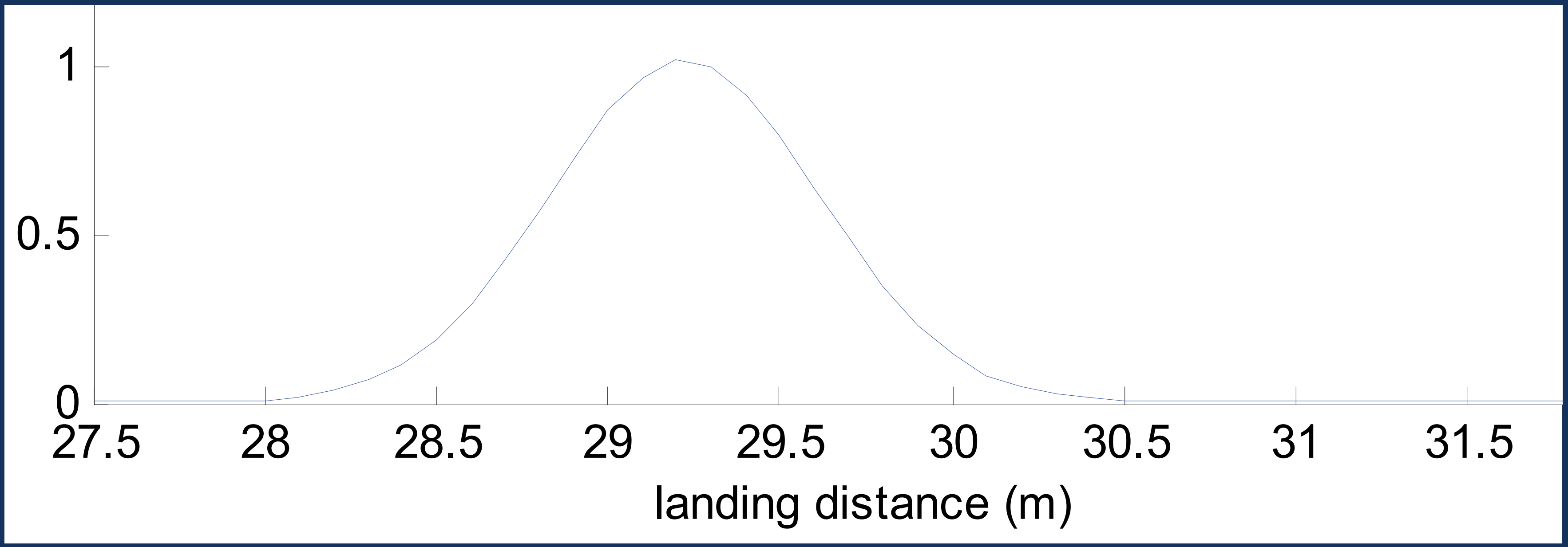
The modified model (results)

- **Example: 300 µm droplets; 3 m/s flow**



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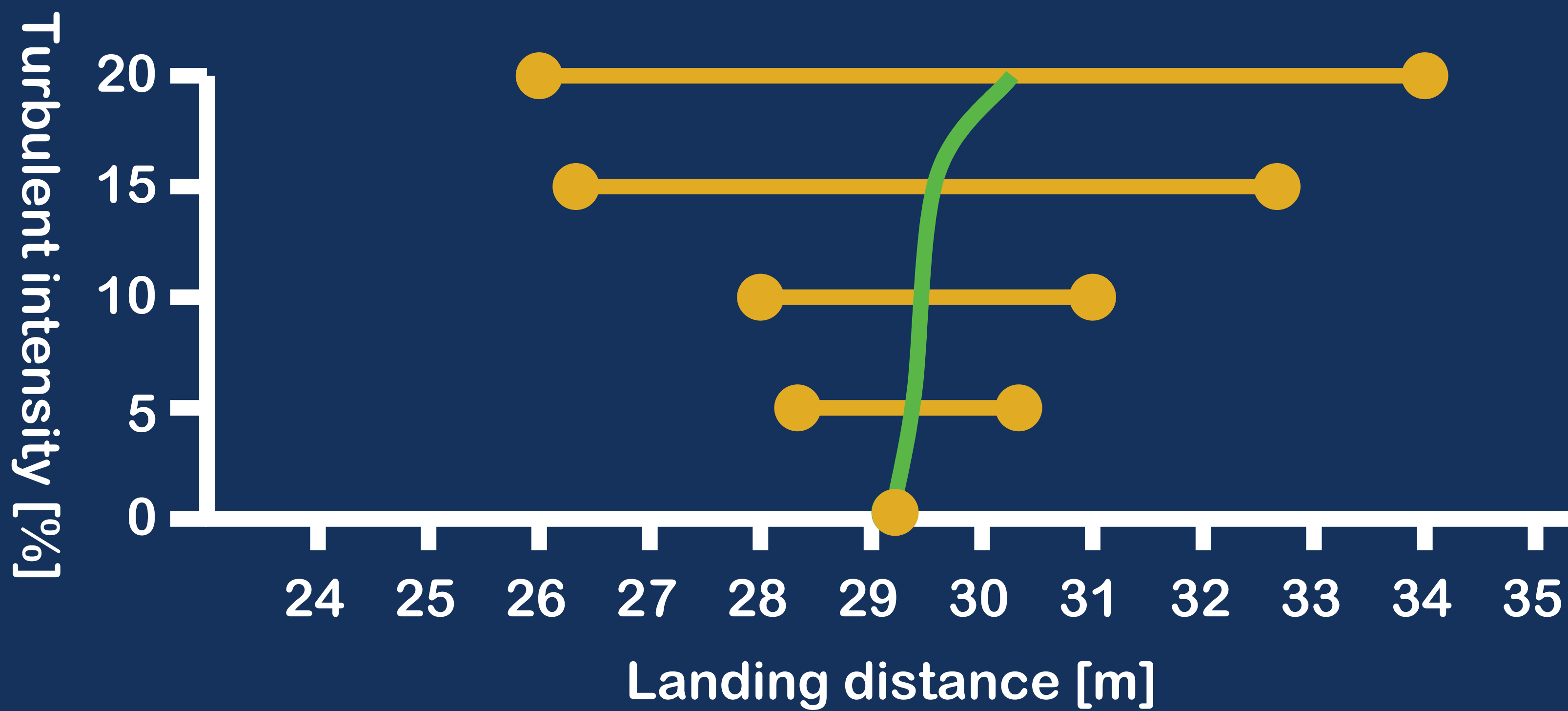
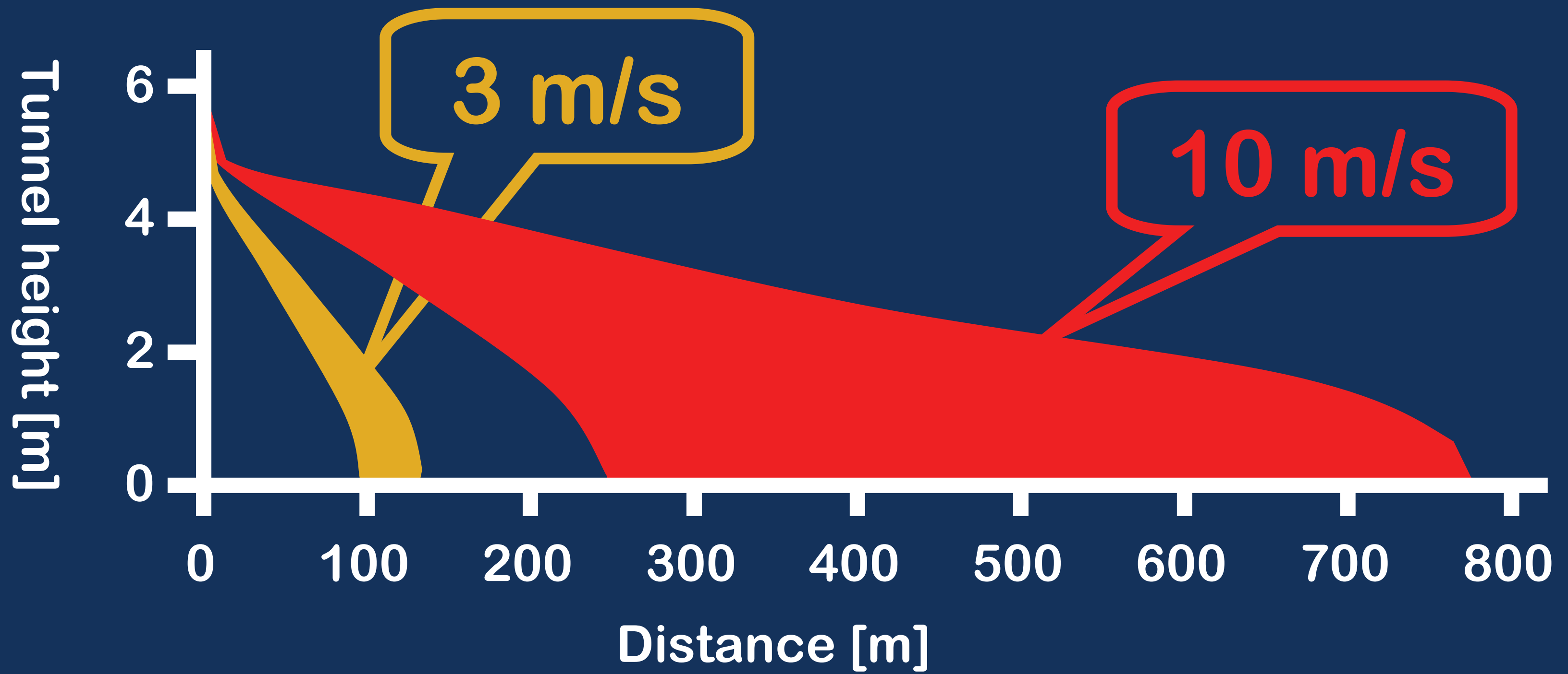
The modified model (results)

- Example: 300 µm droplets; 3 m/s flow



The modified model (results)

- Example: 90 µm droplets



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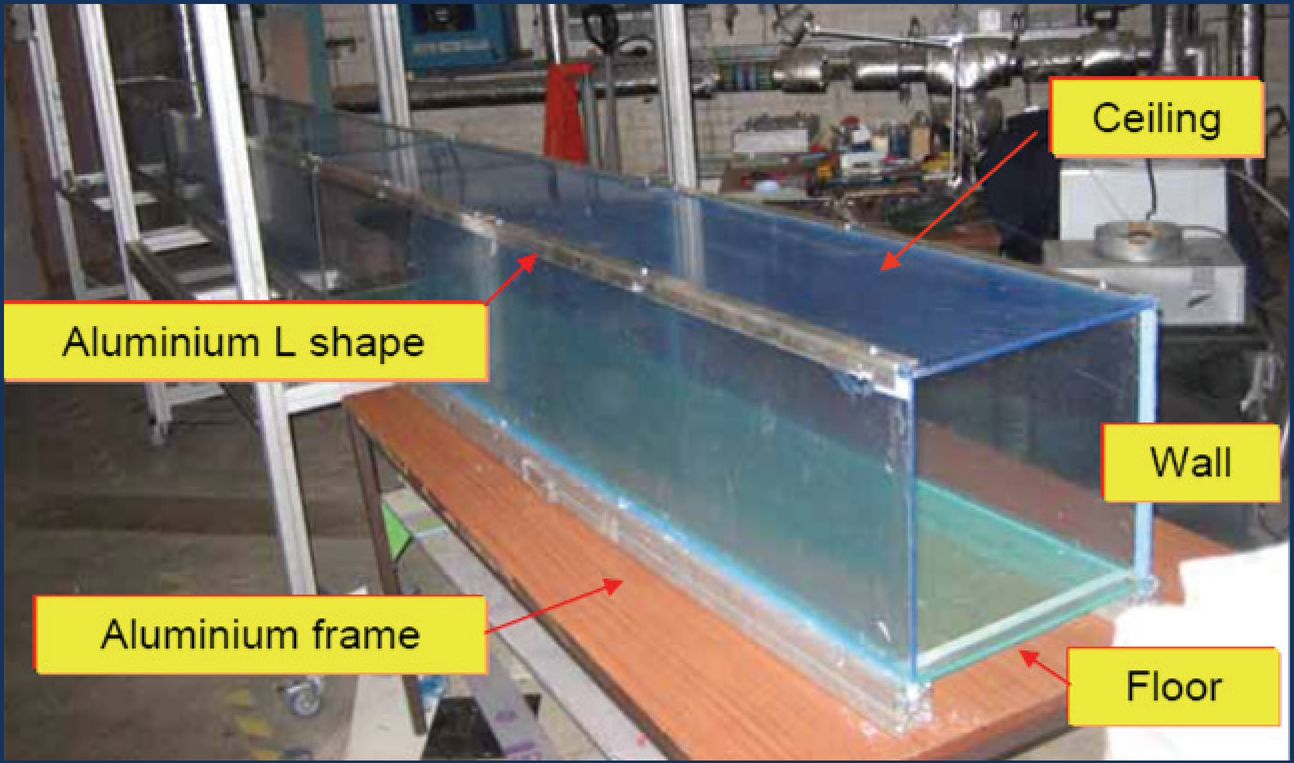
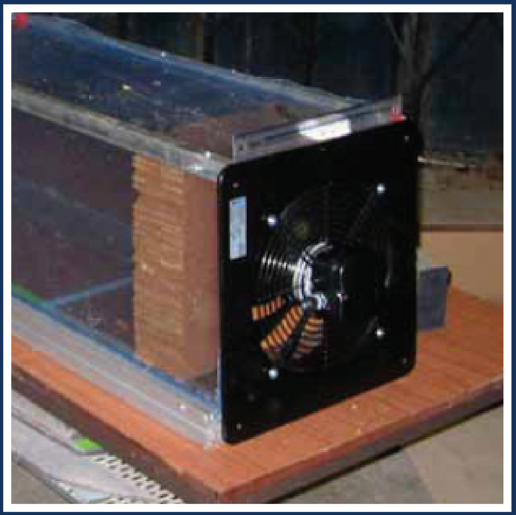
Experimental 'Validation'

- Built a model tunnel in our lab [0.3 x 0.3 x 6.0 m]





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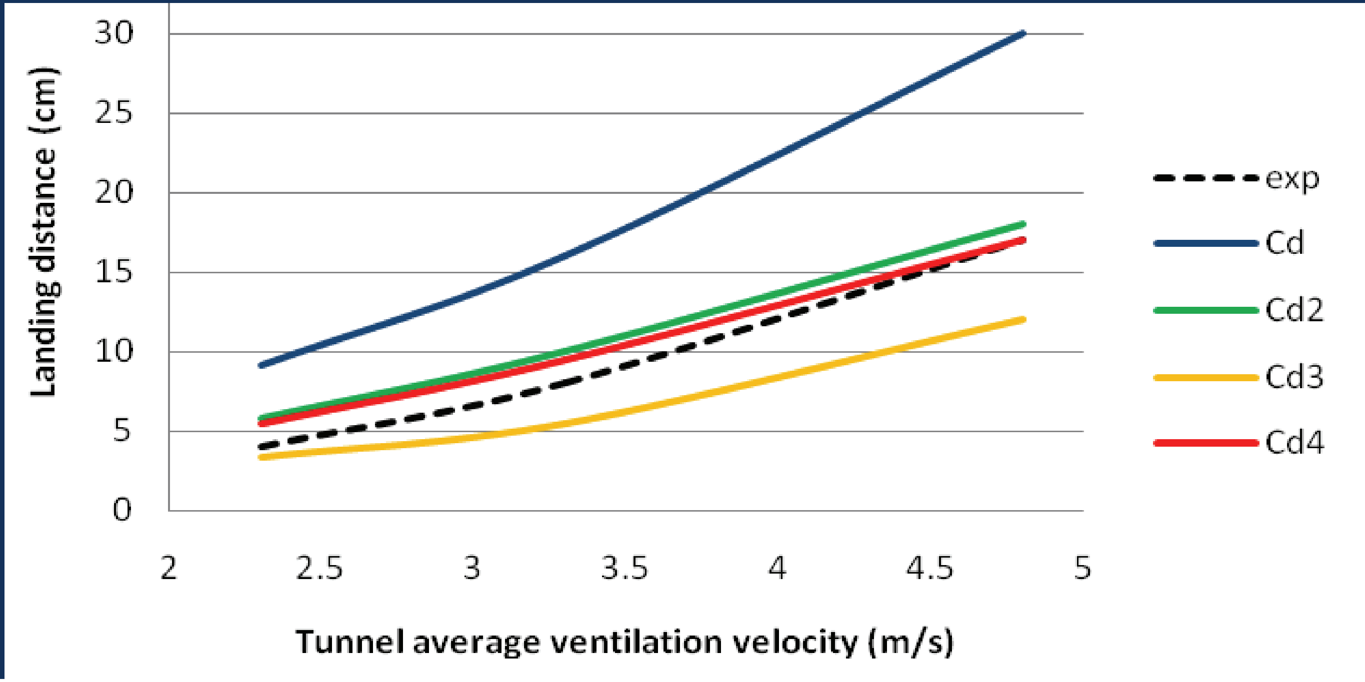
Experimental 'Validation'

- Built a model tunnel in our lab [0.3 x 0.3 x 6.0 m]
- Longitudinal ventilation of 2 to 5 m/s
- Syringe used to inject single droplets [1800 μm]



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CFD 'Validation'

- Used FLUENT CFD code [RANS]
- Lagrangian methods
- Single droplet, various sizes [6 m tunnel, 3 m/s]:
  - Droplet : our model : CFD model [difference]
  - 500 µm : 12.9 m : 11.8 m [9%]
  - 300 µm : 21.3 m : 21.8 m [2.3%]
  - 100 µm : 96.6 m : 96.5 m [0.1%]

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Future work

- Obviously more work to be done…
- Experimental lab work:
  - Mist sized droplets
  - Cloud of droplets
- Model work:
  - Cloud / stream of droplets
- Full scale testing at higher velocities
  - Someone…? Please…?

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Concluding comment

- PIARC: "The aims [of FFFS] are to: slow down fire development, reduce or completely prevent fire from spreading to other vehicles, provide for safe evacuation, maintain tenability for fire-fighting operations, protect the tunnel structure and limit environmental pollution"
- Can this be done at high velocity with a water mist?
- We need to identify the optimum ventilation velocity
- We need to influence those who set the standards

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Thank you for your attention

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