CO-TRACE

Healthy schools through air-quality science

Laboratory Modelling of Ventilation Flows

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   a) Jet/plume interactions
   b) Single person in displacement ventilated room
   c) Two people at different heights
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Research questions/ objectives

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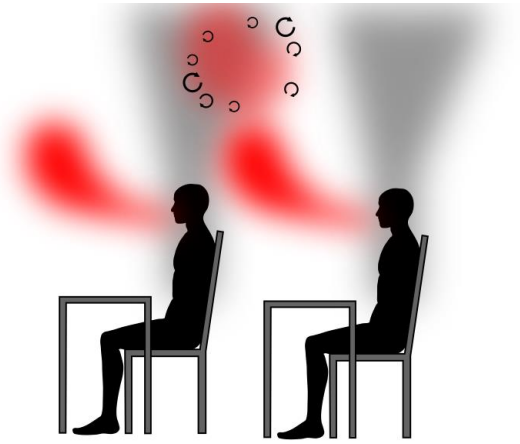
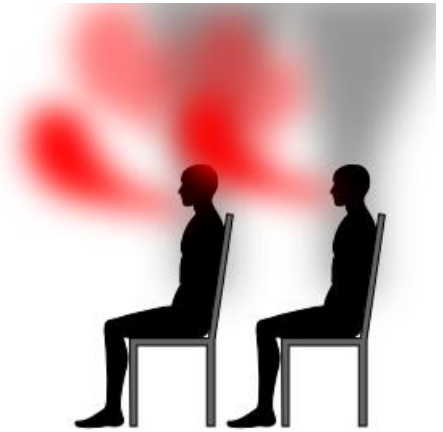
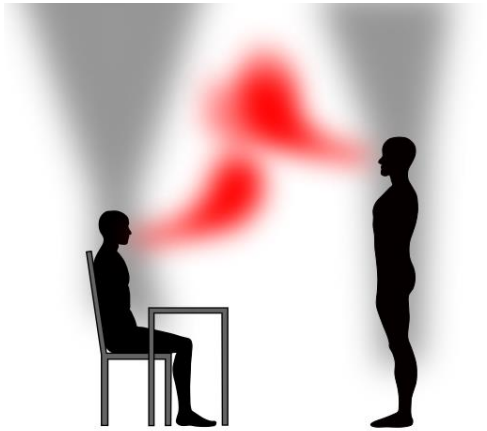
1. Advancing understanding of flows relevant to typical school scenarios
   a) Breath/ body plume interactions
   b) Occupants at different heights
   c) Interaction between interior system and ventilation system (i.e. what is in the room + how it is ventilated)

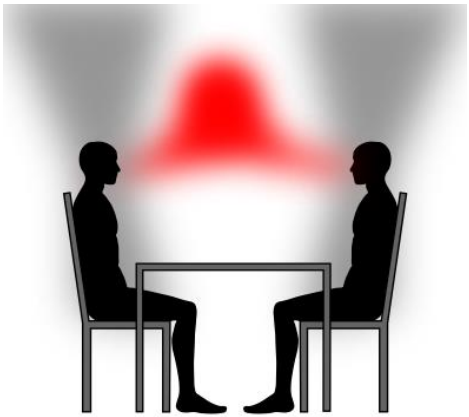
2. How can ventilation be improved?
   a) Retrofit existing systems
   b) Design of new systems

3. Particle concentration a function of CO2?
   a) The effect of steady flow vs intermittent breathing?
   b) The fate of particles (settling, suspension time)









Experiments: Jet/plume interactions in displacement ventilation room

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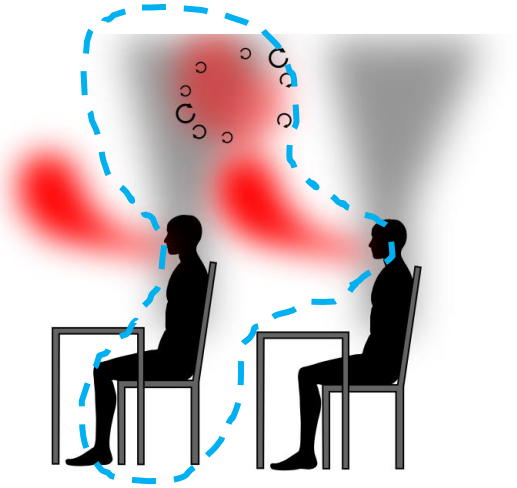
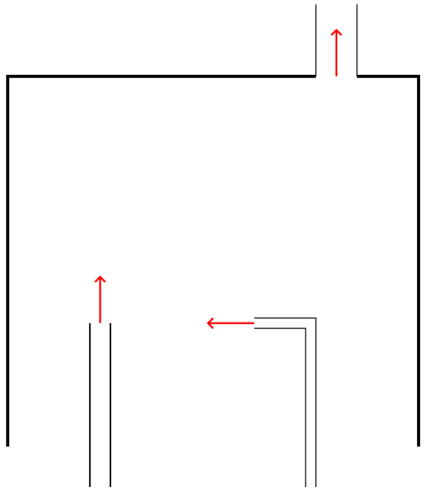
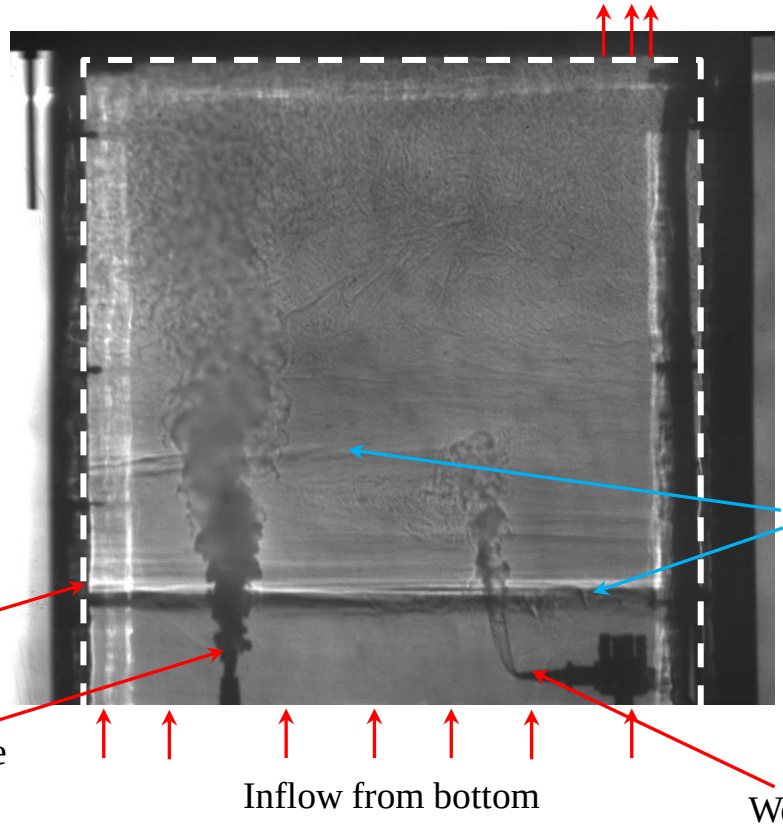




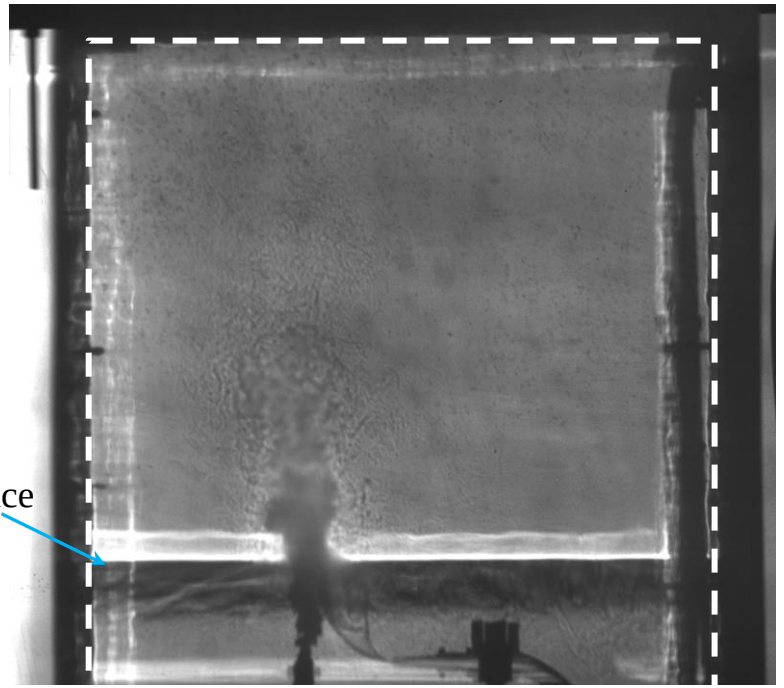
Box immersed in large freshwater tank, salt water used for buoyant fluid

Large separation



Jet buoyancy flux ~ 9.0×10^{-8} m^4 s^{-3}
Plume buoyancy flux ~ 2.2×10^{-6} m^4 s^{-3}

Small separation



Jet buoyancy flux ~ 2.4×10^{-7} m^4 s^{-3}
Plume buoyancy flux ~ 2.2×10^{-6} m^4 s^{-3}

Experiments: Single person in displacement ventilated room. Setup

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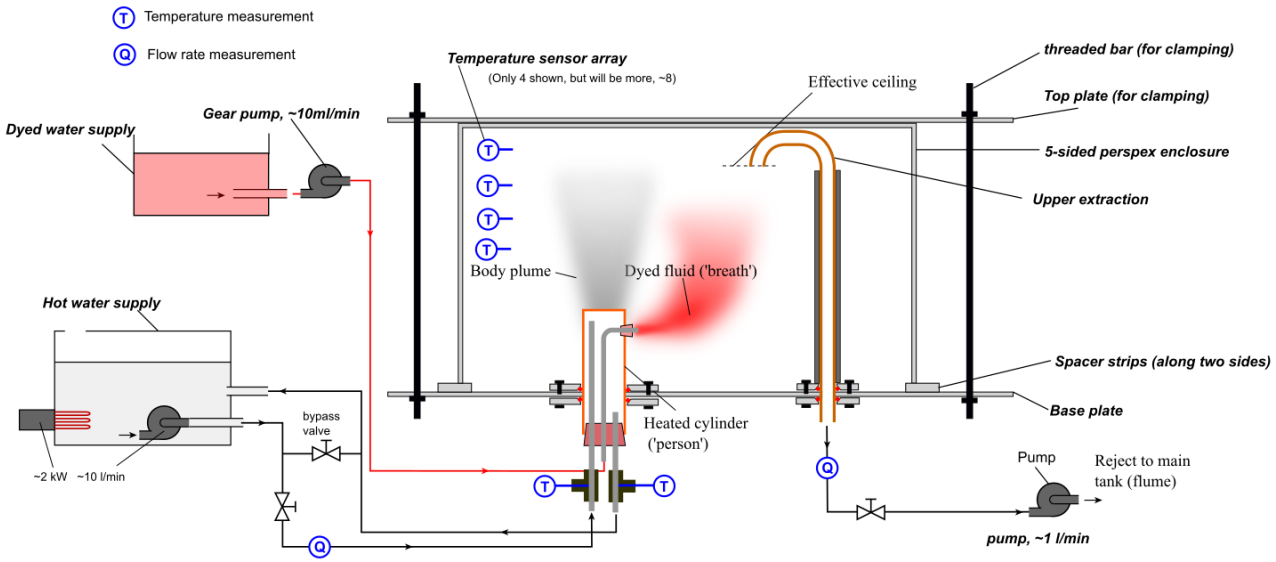
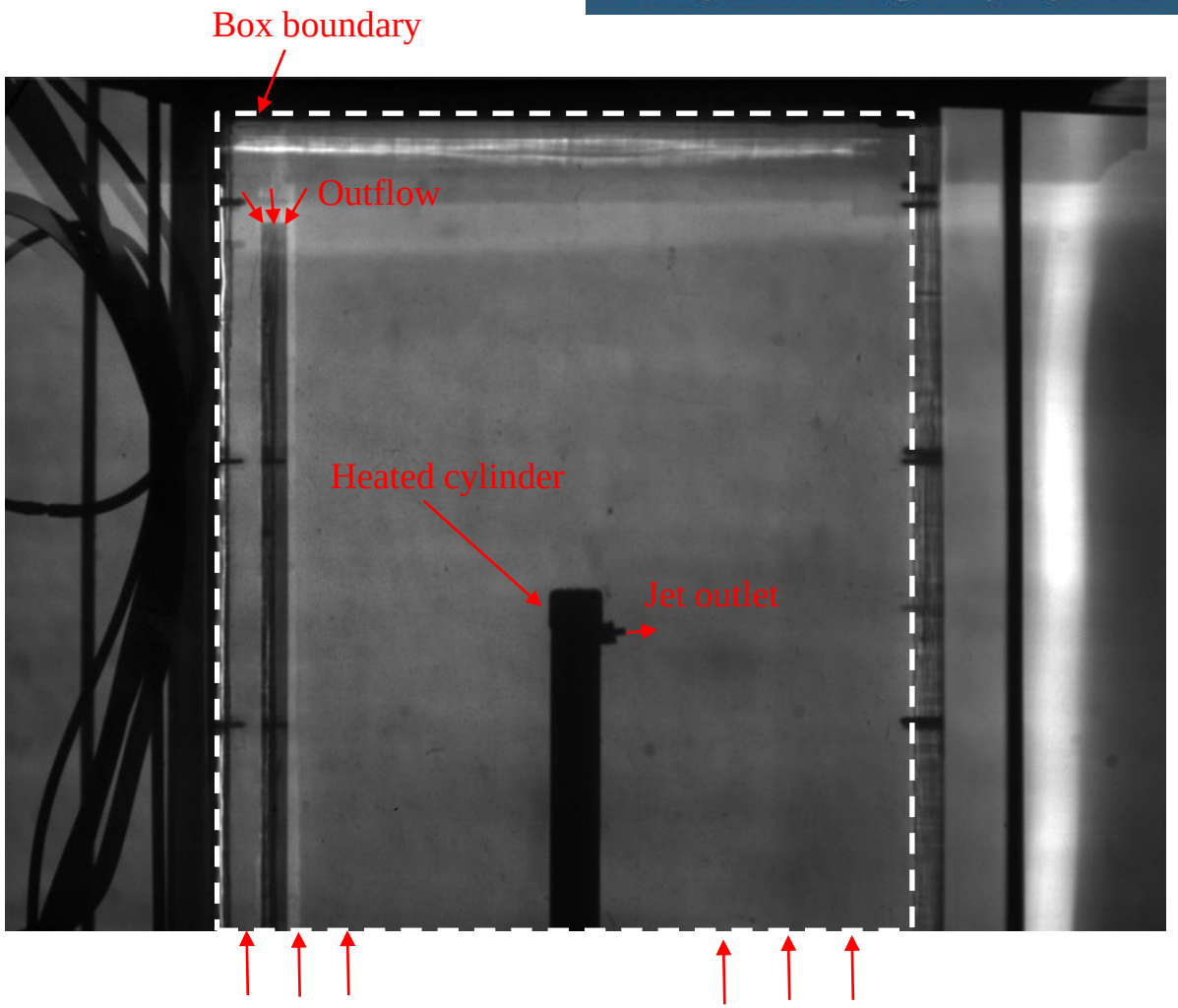


Box cross section, 400x400 mm
Cylinder outer diameter, 28 mm
Breath outlet inner diameter, 2 mm
Hot water supply, 50°C
Ventilation flowrate, 1.12 l min^{-1} (~1.05 ACH)
Breath flowrate, 16.1 ml min^{-1}



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Experiments: Single person in displacement ventilated room. Results

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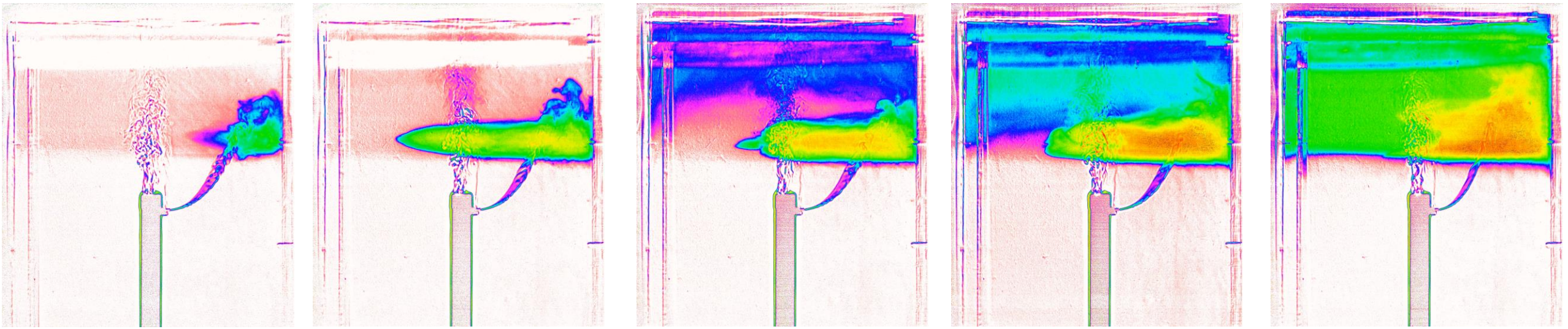
t = 0 min
(Reference)

t = 2 min

t = 10 min

t = 17 min

t = 84 min



Lock-up layer spreads over the cross-section

Lock-up layer entrained in the body plume and carried to top of the room

lock-up layer has not yet spread over full section and is strongly bias to breathing direction

Breath ratio of buoyancy to momentum

Note: The scaling is such that the model is equivalent to ~3 l min^{-1} breathing rate, (by matching $\frac{D^5 \beta g \Delta T}{Q^2} = 0.28$)

Experiments: Two people at different heights

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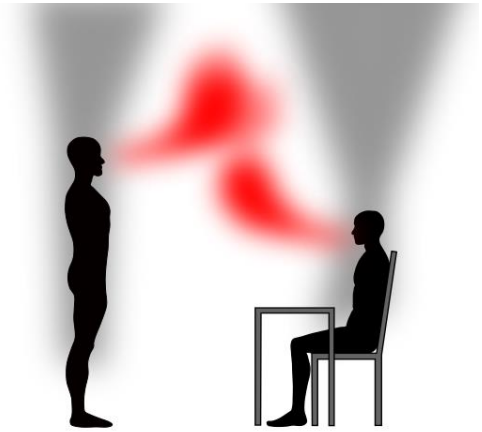
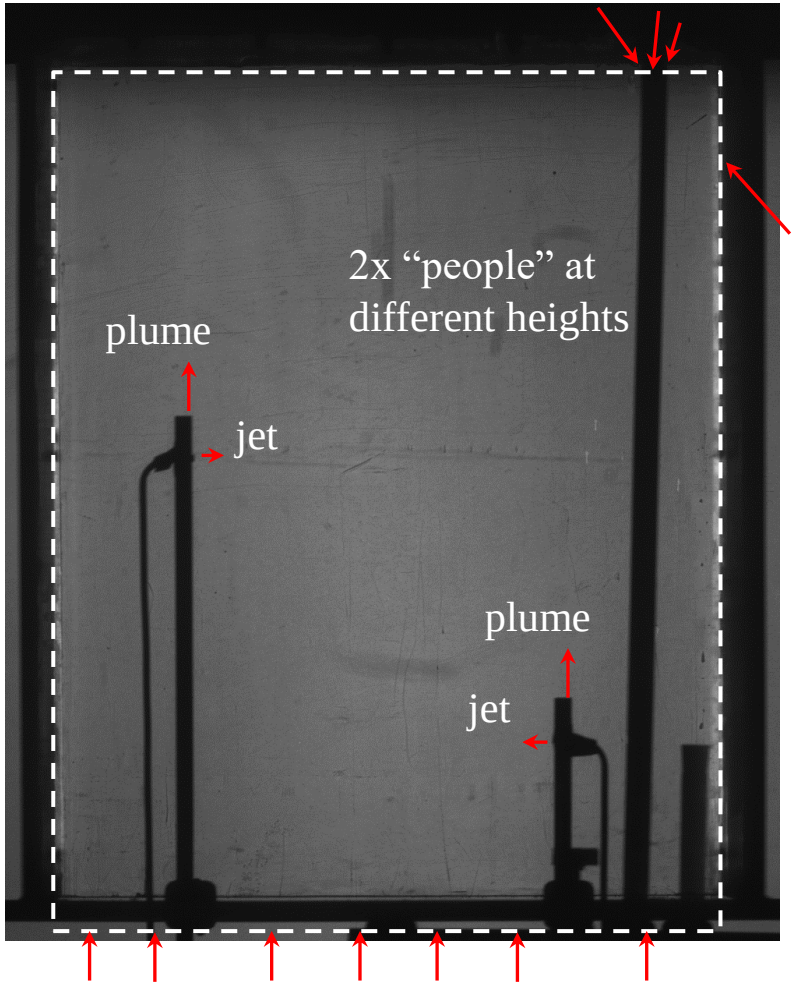


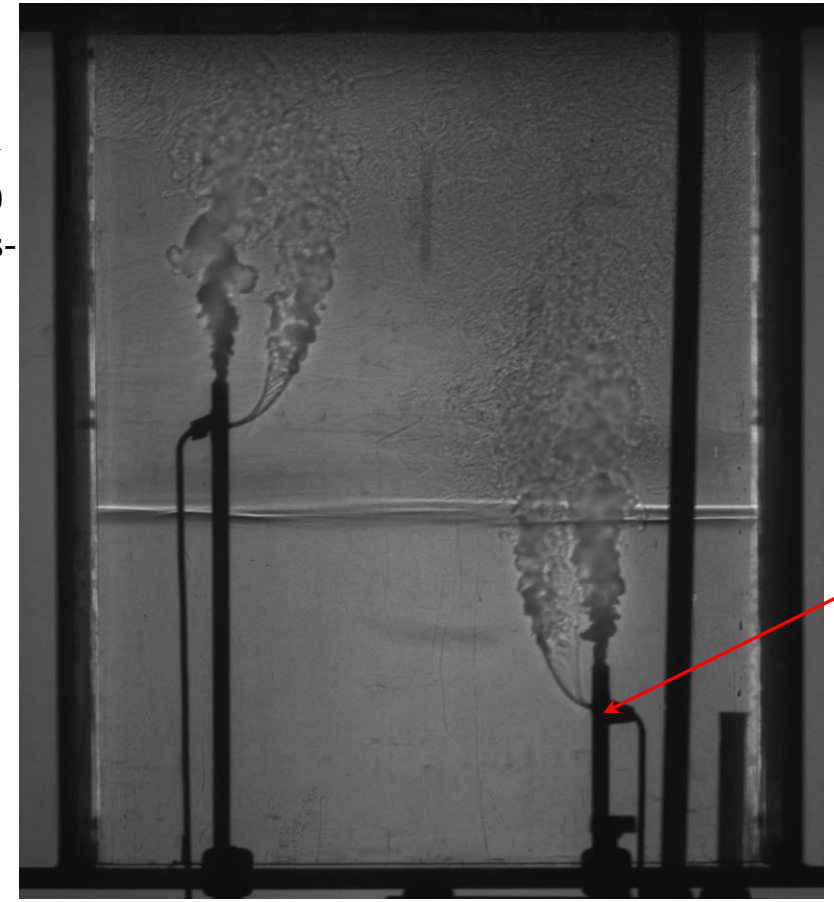
Extraction at top



Box boundary (400x400 mm cross-section)

Inflow from bottom

(video at x20 speed)



The lower “breath” outlet is dyed

Note: @1:09, upper plume fails

Experiments: ‘improving’ ventilation by lowering extraction height?
Setup 1

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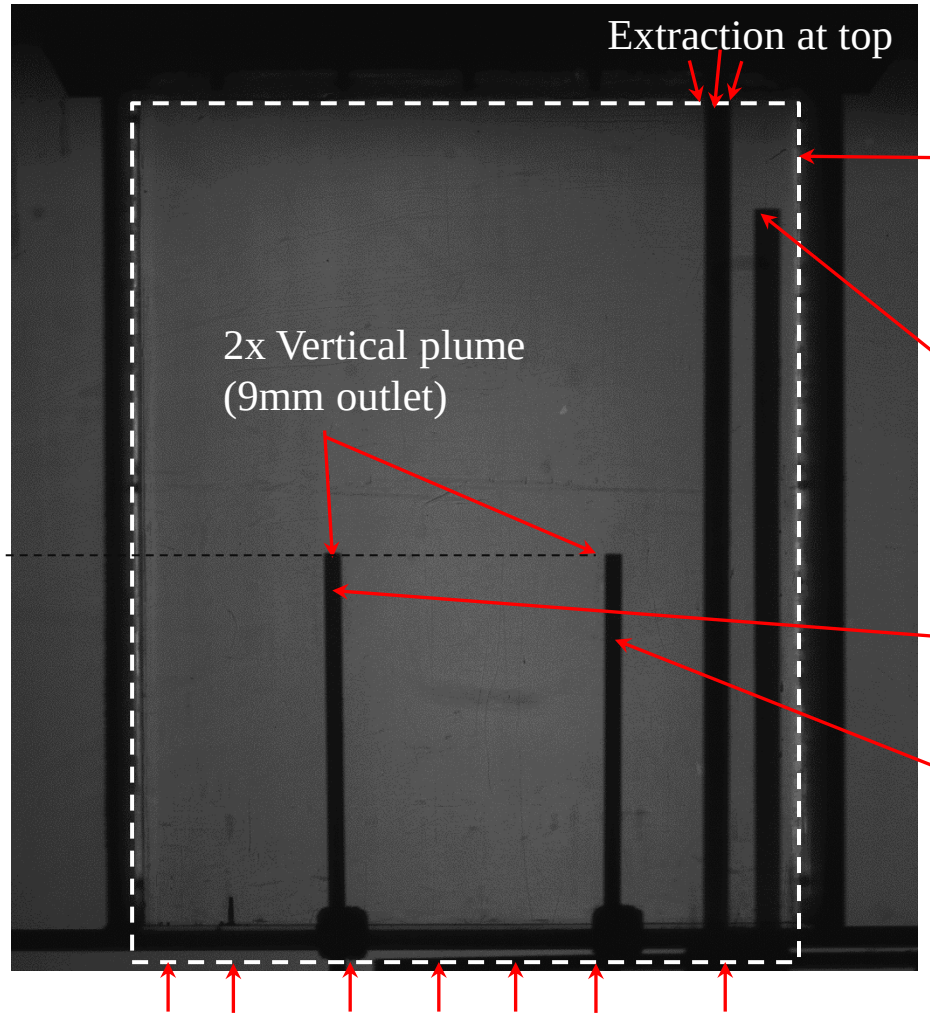

Box boundary (400x400mm cross-section)

Secondary lower
extraction
(adjustable height)

Stronger plume (not dyed),
$B_1 = 1.93 \times 10^{-6}\ m^4 s^{-3}$

Weaker plume (dyed),
$B_2 = 1.12 \times 10^{-6}\ m^4 s^{-3}$

Ratio,
$B_1/B_2 = 1.7$

Experiments: ‘improving’ ventilation by lowering extraction height?
Results 1

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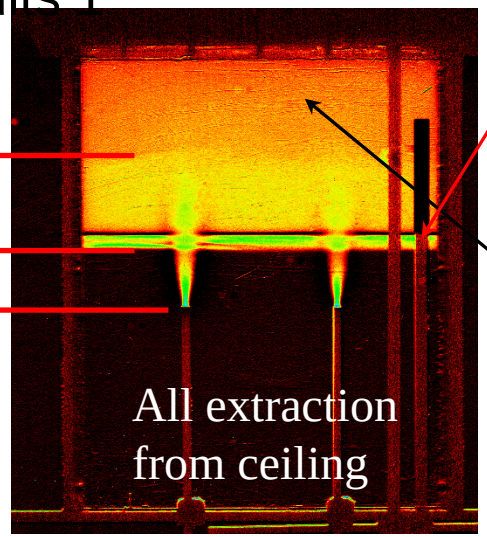
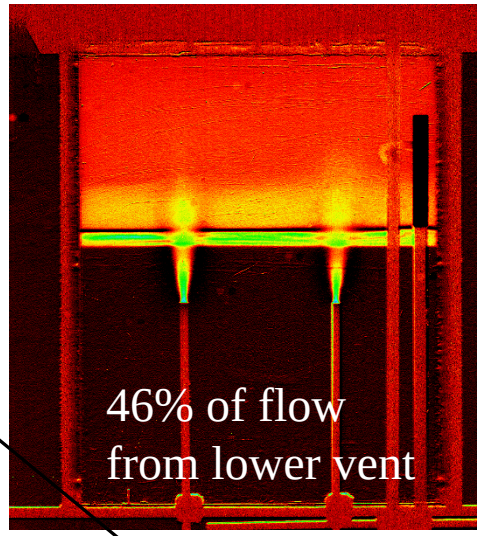
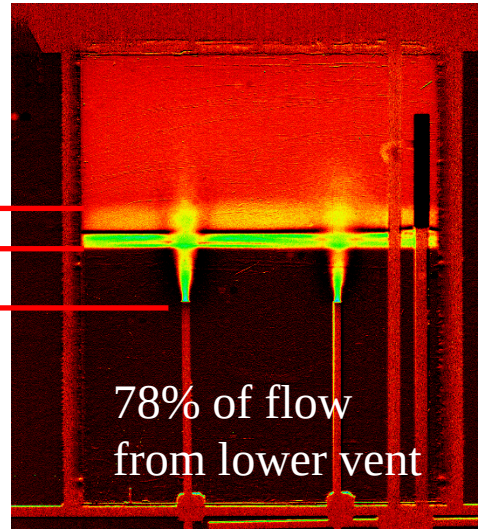
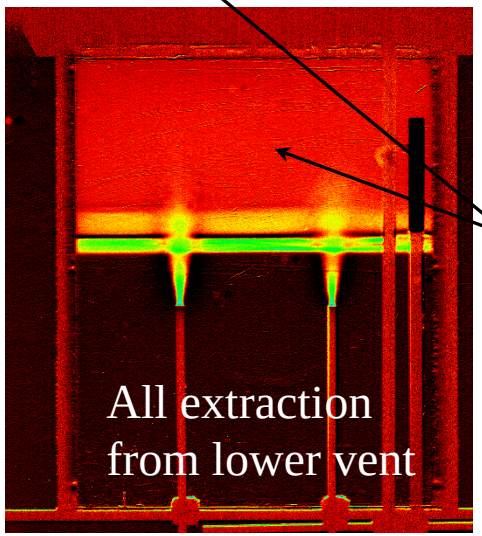
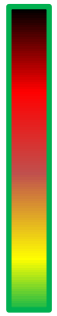


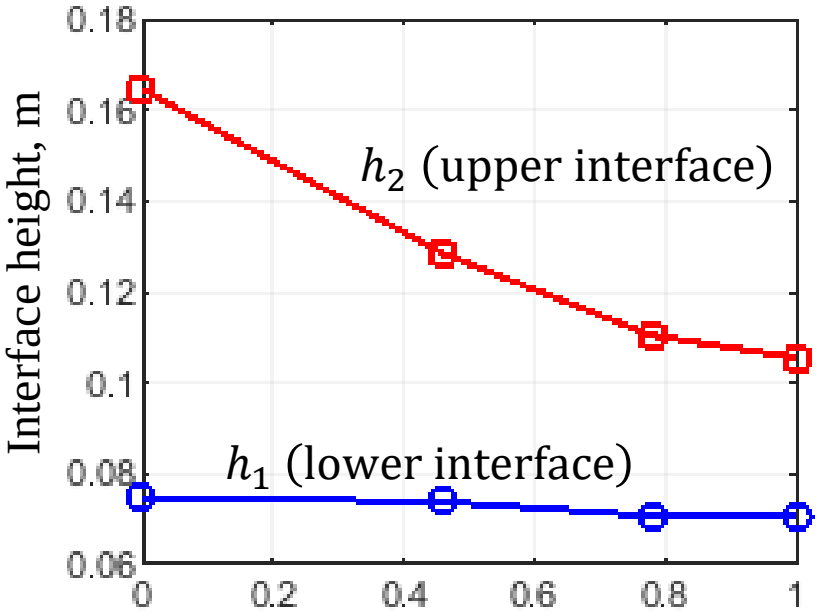
Lower vent in lock-up layer











Much lower dye concentration in upper layer with lower vs upper vent

Flowrate fraction from lower vent, $= Q_2/(Q_1 + Q_2)$.
[total flow $Q_1 + Q_2 = 4.08$ l/min for all cases]

Experiments: ‘improving’ ventilation by lowering extraction height?
Setup 2

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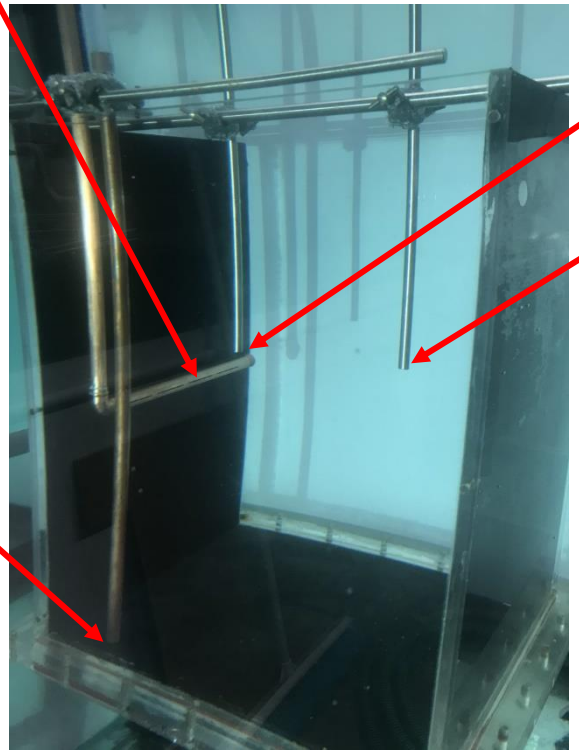
Thin (1mm) silts used to extract at specific vertical height



Plume 1 outlet

Plume 2 outlet (dyed)

Upper (gravity flipped) extraction

During experiment

Note extraction height is below the main interface

Experiments: ‘improving’ ventilation by lowering extraction height?
Results 2

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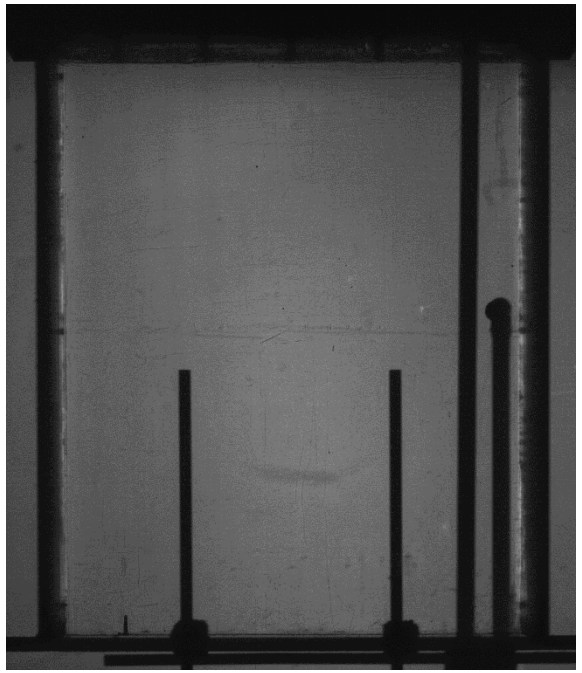
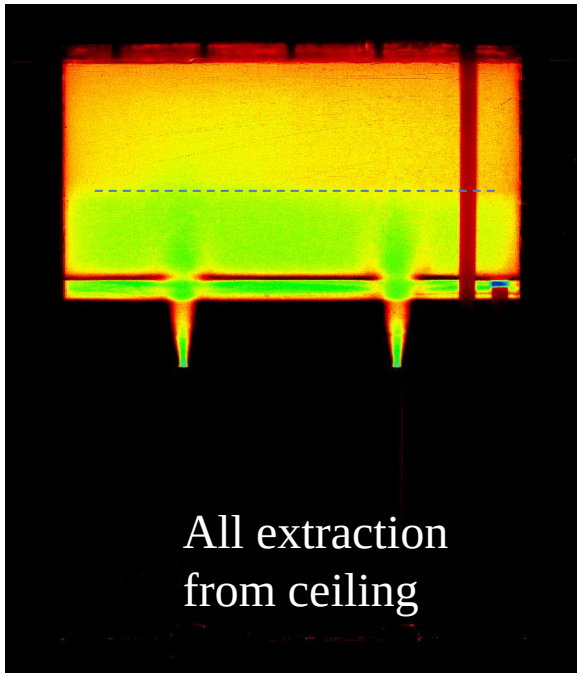
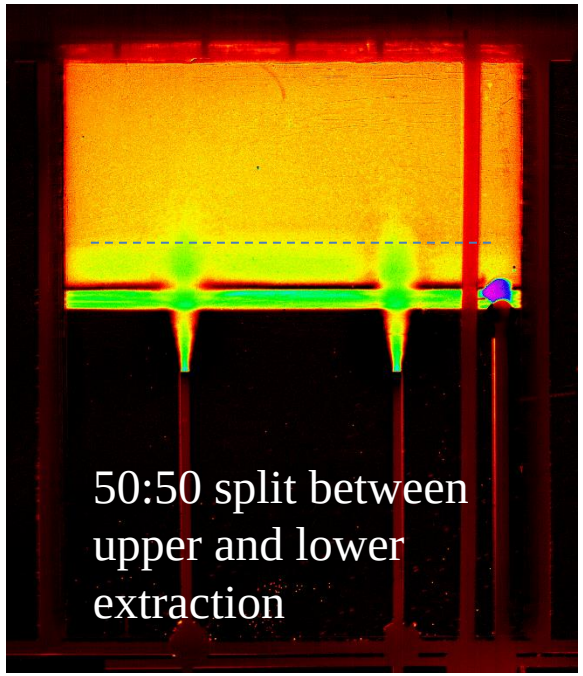
(background image)

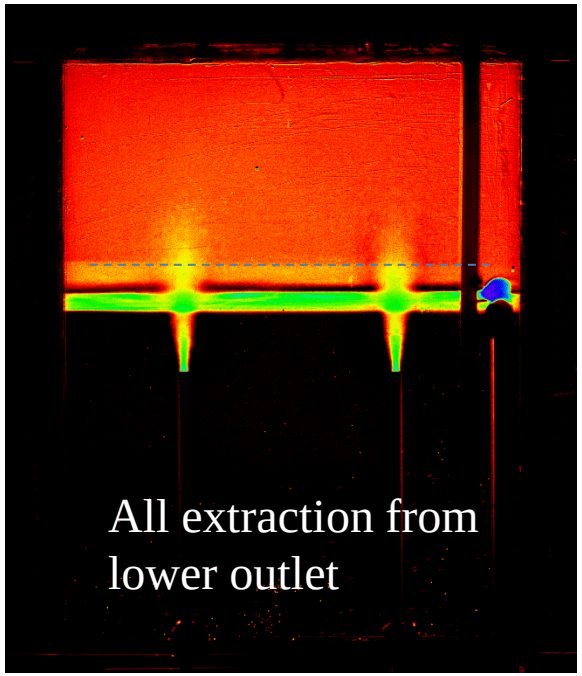
(processed images)

Total ventilation flowrate: 3.67 l min^{-1}
Plume 1 buoyancy flux: $2.02 \times 10^{-6}\ m^4 s^{-3}$
Plume 2 buoyancy flux: $1.04 \times 10^{-6}\ m^4 s^{-3}$









Conclusions/ Further work

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1. In reality, ‘how the room is used’ and ‘how the room is ventilated’ presents an vast number of possible scenarios.
2. We can study simplified scenarios that can guide our understanding of the larger system and/or be used to validate simulations
3. Future work will include
   a) Mathematical modelling of the variable extraction height system
   b) Revisiting and refining experiments of jet/plume interactions
   c) Experiments to date have used displacement ventilation. It is planned to consider single sided natural ventilation in the future.
   d) Investigating the impact of intermittent vs steady flow for exhaled breath