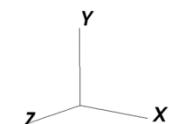
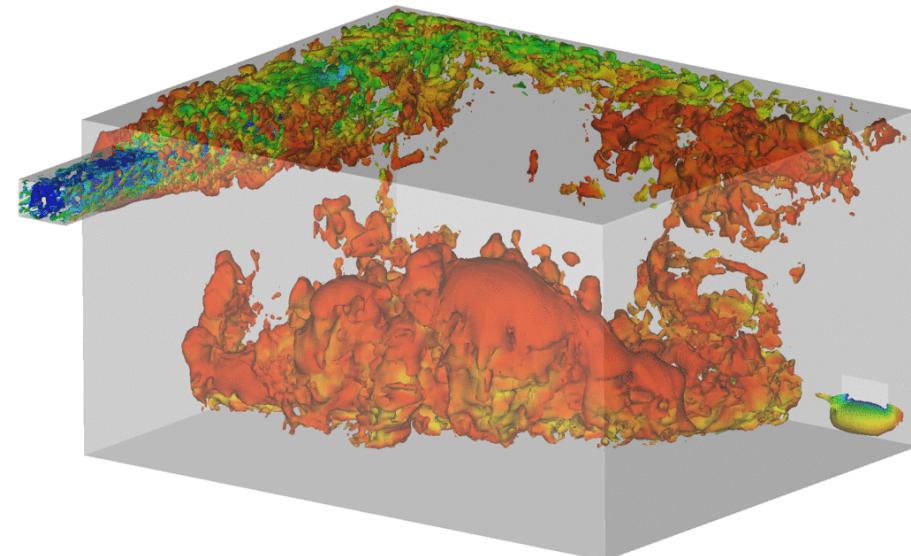


Quantifying the Potential of Covid-19 Transmission Across Scales: Using SEM based Navier-Stokes solver to the CEAT

Som Dutta

Mechanical & Aerospace Engineering
Utah State University

Alex Fabregat, Universitat Rovira i Virgili
Jordi Pallares, Universitat Rovira i Virgili
Ketan Mittal, LLNL
K Rao, ANL
Brian J. Schimmoller, Signature Sc. LLC
Afshin Beheshti , NASA & Cov-IRT
Nídia S. Trovão, NIH
Paul Fischer, UIUC
Neil Lindquist,
Misun Min
Ramesh Balakrishnan, ANL



Som Dutta, Ketan Mittal and Paul Fischer

GOAL: Accurate Prediction of Virus Loading in Indoor Environments

- Currently it is motivated by COVID-19, but the methodology can be used for other respiratory viruses in the future
- Understand the process involved in virus-laden aerosol mixing and transport
- Predict the most probable regions of virus-laden aerosol accumulation and deposition, which will help us to plan

Mitigation Strategies & Compute Risk of Transmission

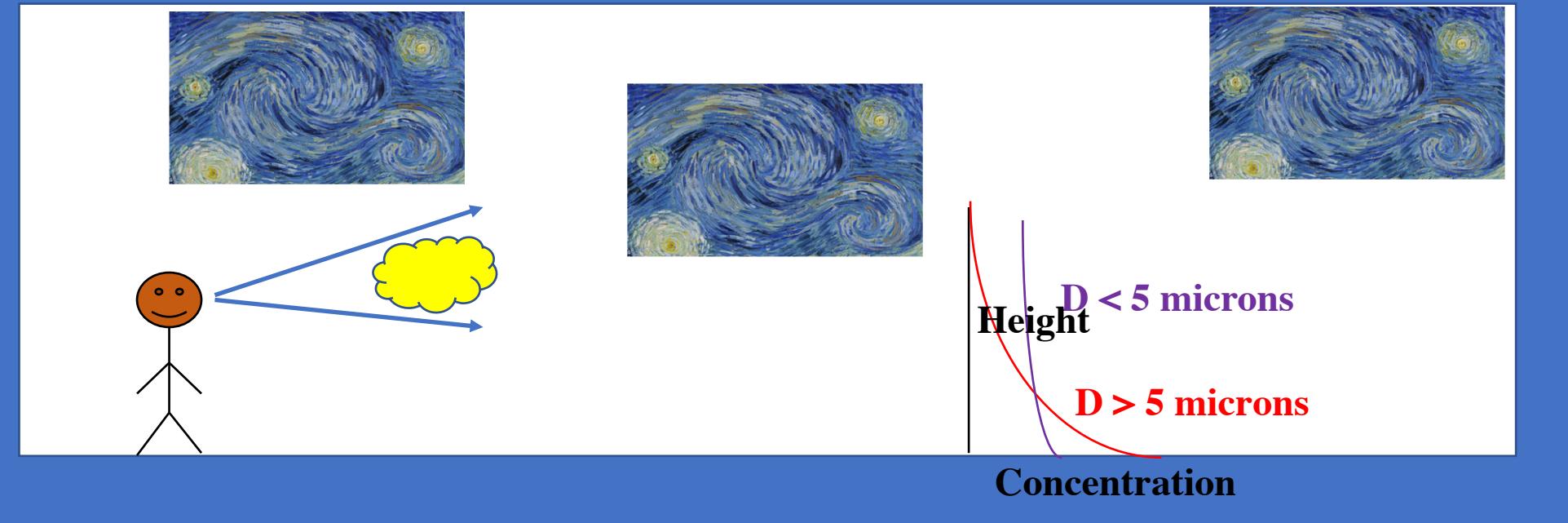


Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community

Jing Yan^{a,b}, Michael Grantham^{a,1}, Jovan Pantelic^{a,2}, P. Jacob Bueno de Mesquita^a, Barbara Albert^a, Fengjie Liu^{a,3}, Sheryl Ehrman^{b,4}, Donald K. Milton^{a,5}, and EMIT Consortium⁶

^aMaryland Institute for Applied Environmental Health, School of Public Health, University of Maryland, College Park, MD 20742; and ^bDepartment of Chemical and Biomolecular Engineering, Clark School of Engineering, University of Maryland, College Park, MD 20742

Edited by Peter Palese, Icahn School of Medicine at Mount Sinai, New York, NY, and approved December 15, 2017 (received for review September 15, 2017)



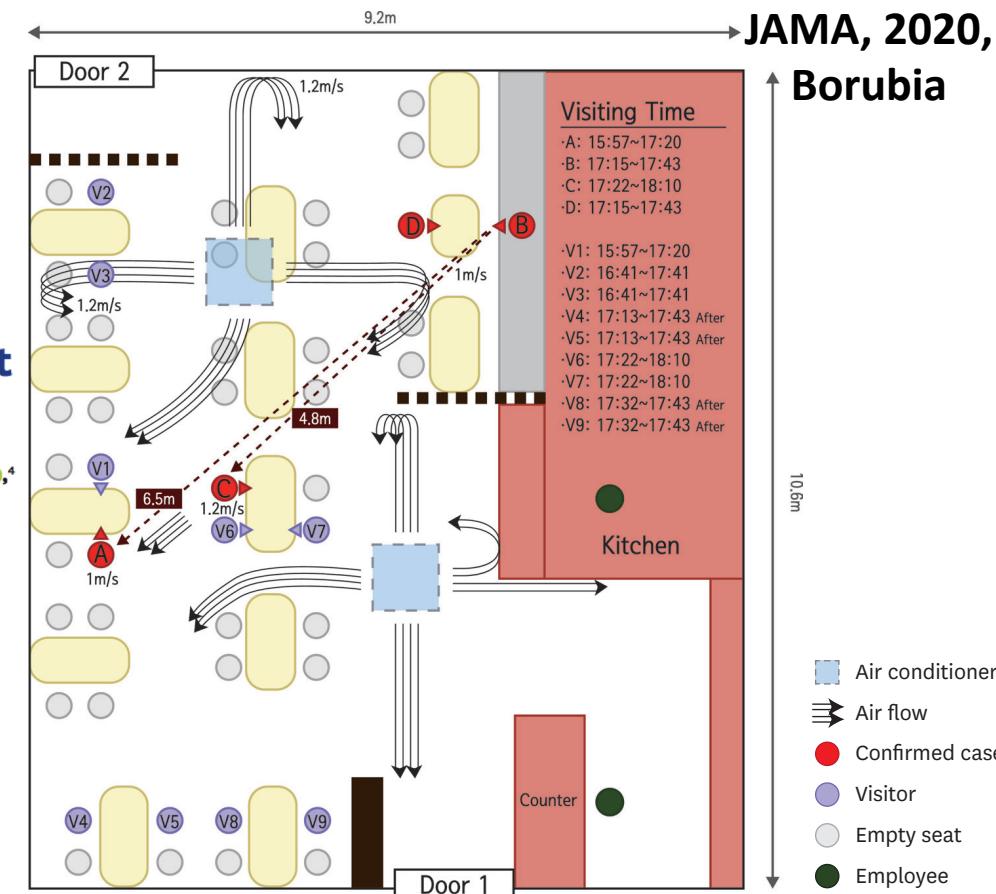
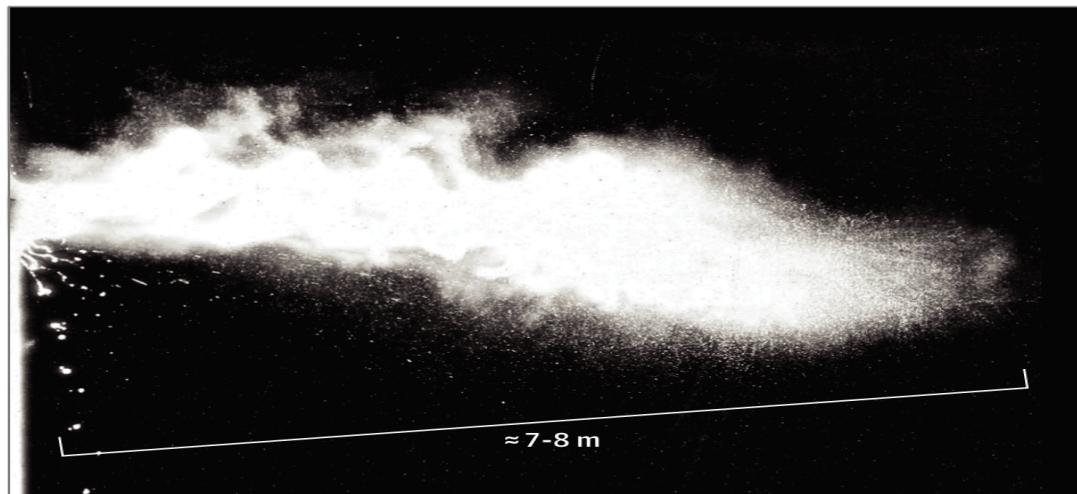
Modes of Airborne Virus Spreading in the Indoor Environment

- Pre-pandemic, we thought the main mode of airborne transmission of viruses is through coughing and sneezing
- “Asymptomatic” or “Pre-symptomatic” transmission of Covid-19 has made us question our existing understanding of airborne transmission, especially in the indoor environment

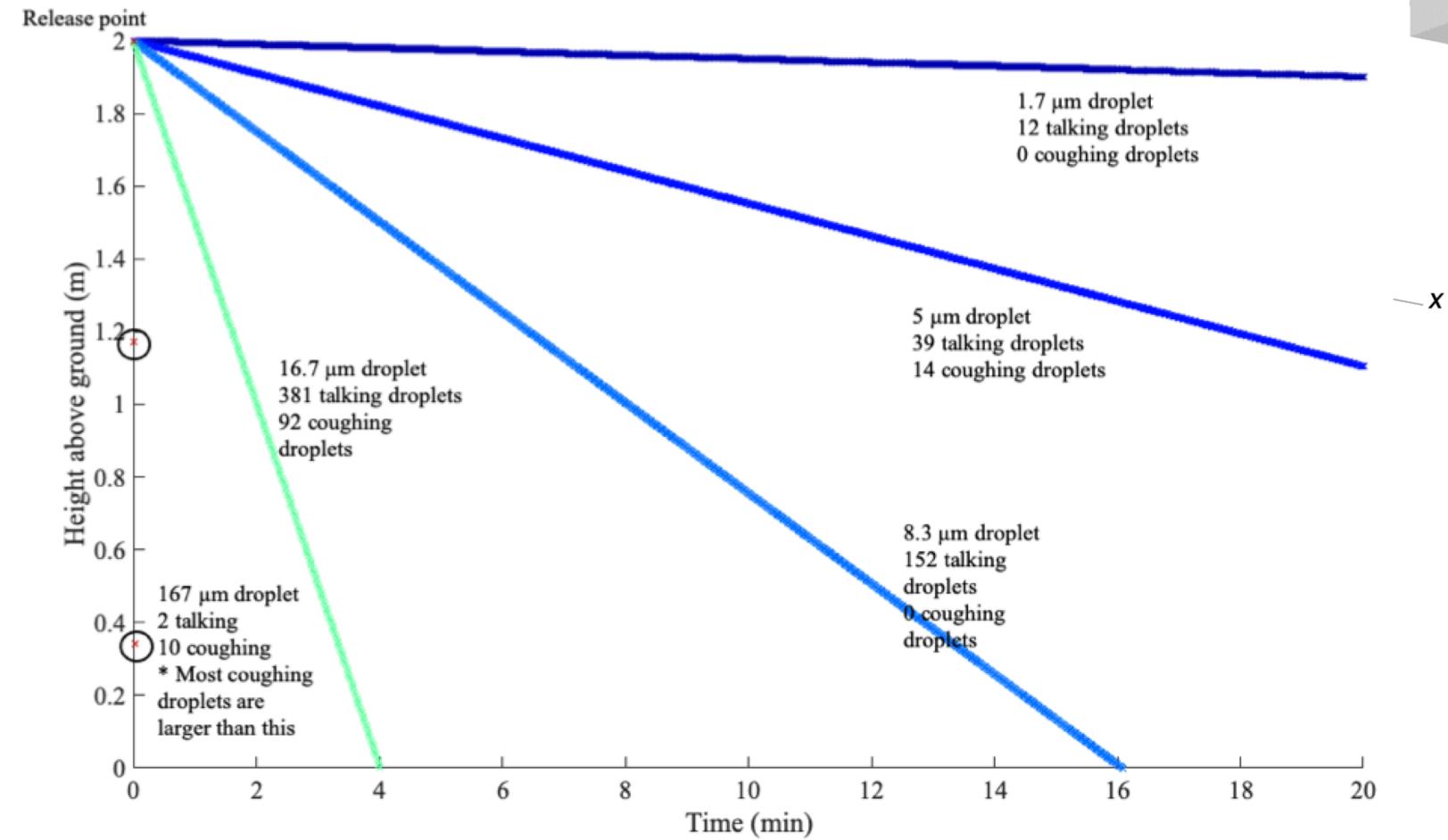
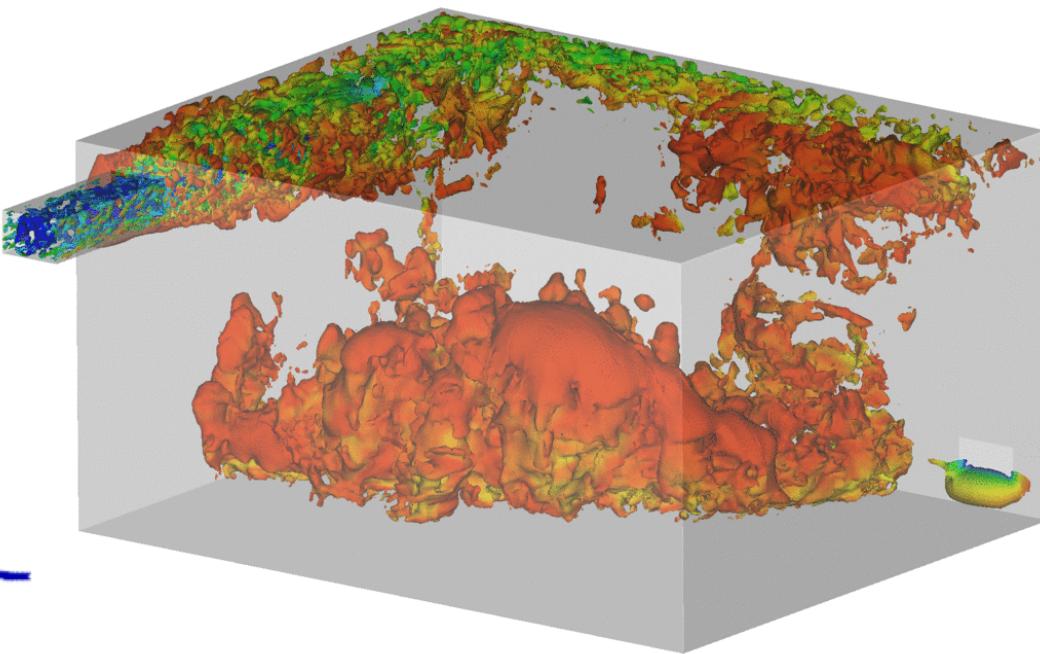
Evidence of Long-Distance Droplet Transmission of SARS-CoV-2 by Direct Air Flow in a Restaurant in Korea

Keun-Sang Kwon ,^{1,2*} Jung-Im Park ,^{2*} Young Joon Park ,³ Don-Myung Jung ,⁴ Ki-Wahn Ryu ,⁵ and Ju-Hyung Lee ,^{1,2}

- If the virus-laden aerosols are helping spread SARS-CoV-2, then it is extremely important understand the spatio-temporal evolution of the aerosols especially in the size range of 0.5 – 20 microns



Size of Virus-Laden Aerosol Cloud and what mode will it be transmitted



Som Dutta, Ketan Mittal and Paul Fischer

Isosurface of vertical velocity zones that are high enough to keep 5 micron or lower, aerosols in suspension

If we are using Computational Fluid Dynamics, what level of fidelity is required to accurately capture the aerosol transport ?

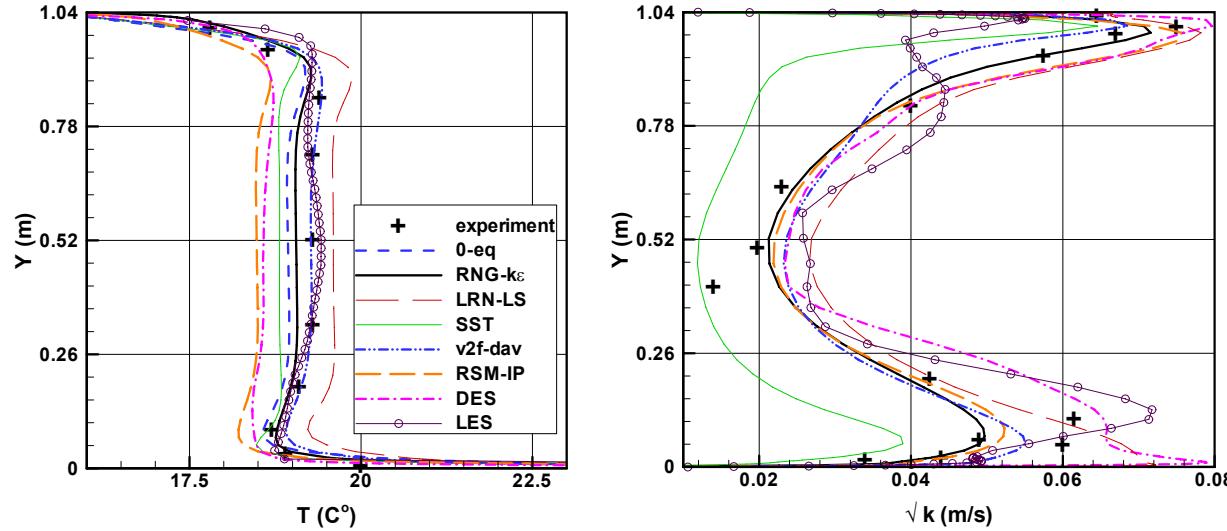
Evaluation of Various Turbulence Models in Predicting Airflow and Turbulence in Enclosed Environments by CFD: Part-2: Comparison (2007) with Experimental Data from Literature

Zhao Zhang
Student Member ASHRAE

Wei Zhang
Member ASHRAE

Zhiqiang Zhai
Member ASHRAE

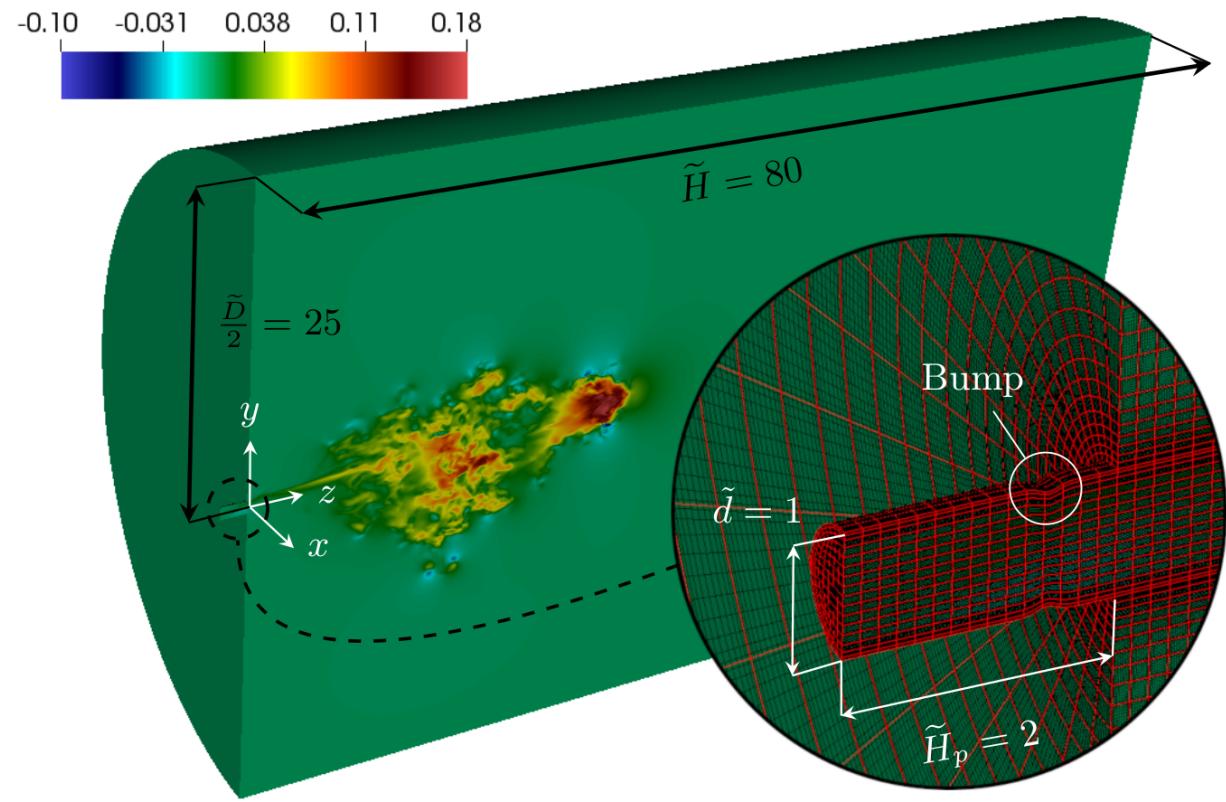
Qingyan Chen*
Fellow ASHRAE



While each turbulence model has good accuracy in certain flow categories, each flow type favors different turbulence models. Therefore, we summarize both the performance of each particular model in different flows and the best suited turbulence models for each flow category in the conclusions and recommendations.

So we decided to do Direct Numerical Simulation (DNS) or highly-resolution LES, which resolves almost all the relevant scales of turbulence

First problem we targeted is: DNS of a small cough

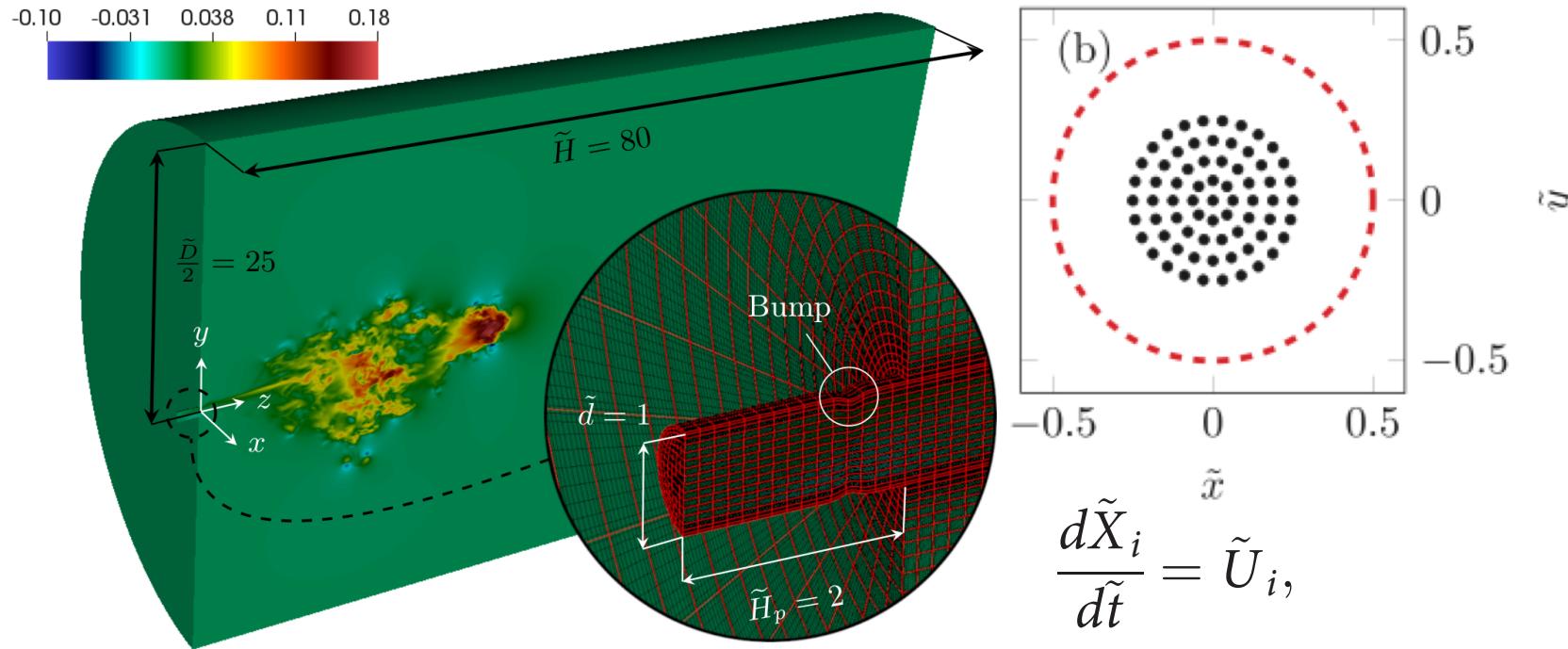


$$w_0(t) = \begin{cases} \frac{w_m}{t_m} t, & 0 \leq t < t_m \\ w_m - \frac{w_m}{t_c - t_m} (t - t_m), & t_m \leq t \leq t_c \\ 0. & t > t_c \end{cases}$$

$$\begin{aligned} \frac{\partial \tilde{u}_i}{\partial \tilde{x}_i} &= 0, \\ \frac{\partial \tilde{u}_i}{\partial \tilde{t}} + \tilde{u}_j \frac{\partial \tilde{u}_i}{\partial \tilde{x}_j} &= -\frac{\partial \tilde{p}}{\partial \tilde{x}_i} + \frac{1}{Re} \frac{\partial^2 \tilde{u}_i}{\partial \tilde{x}_j \partial \tilde{x}_j} + Ri \tilde{\theta} \delta_{i2}, \\ \frac{\partial \tilde{\theta}}{\partial \tilde{t}} + \tilde{u}_j \frac{\partial \tilde{\theta}}{\partial \tilde{x}_j} &= \frac{1}{Pe} \frac{\partial^2 \tilde{\theta}}{\partial \tilde{x}_j \partial \tilde{x}_j}, \end{aligned}$$

$$Re = w_m d / \nu_a = 6000, \quad Ri = g \beta_a \Delta T d / w_m^2 = 5.61 \times 10^{-4} \quad \text{and} \quad Pe = w_m d / \alpha_a = 4200.$$

First problem we targeted is: DNS of a small cough



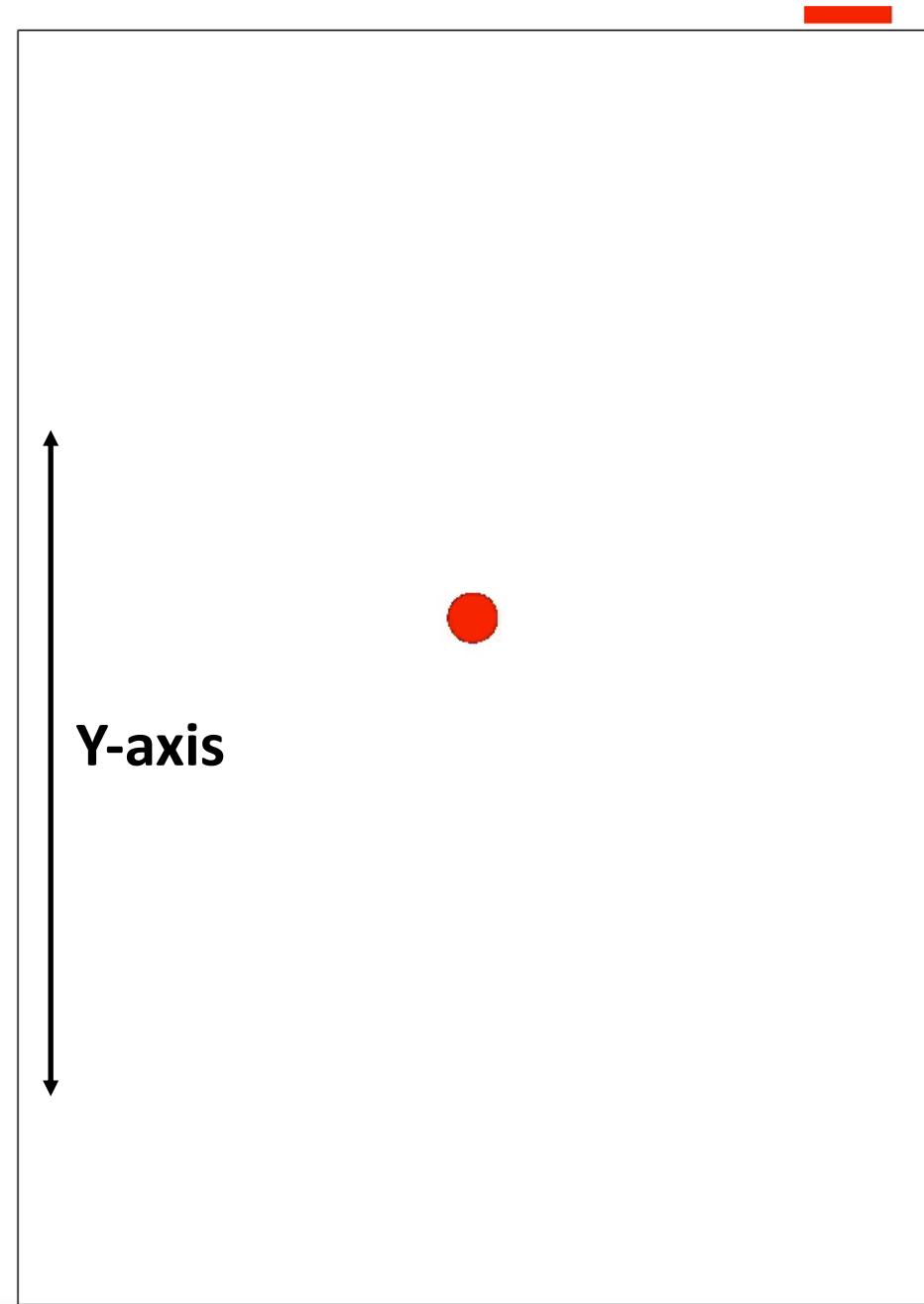
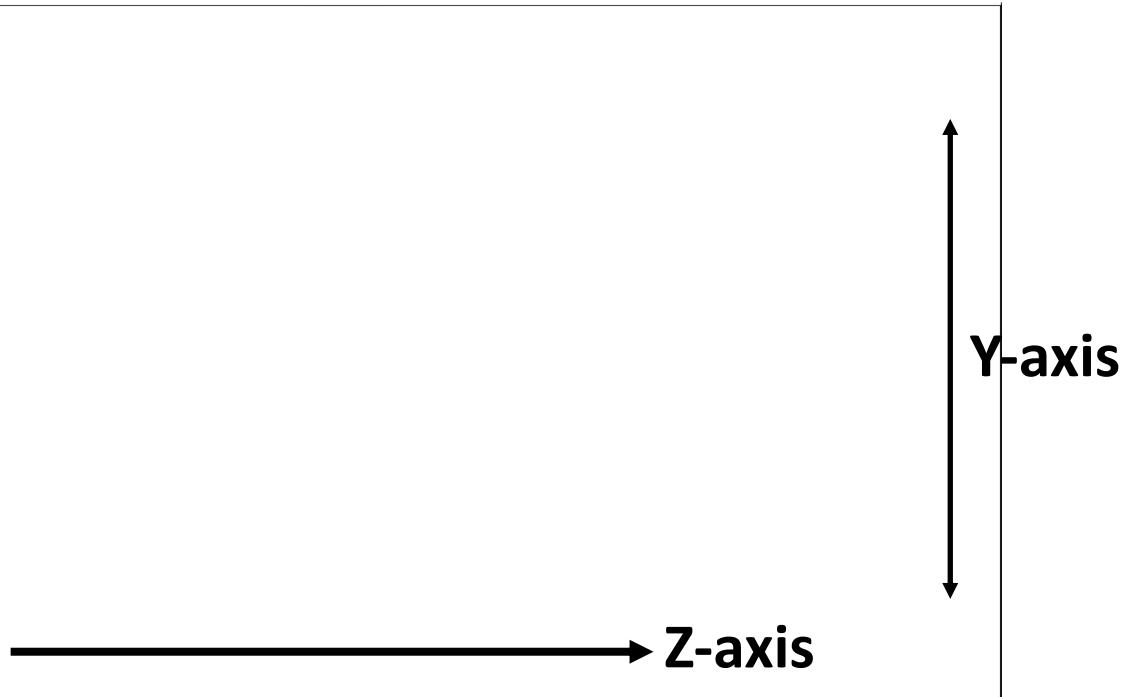
$$\frac{d\tilde{X}_i}{d\tilde{t}} = \tilde{U}_i,$$

$$\frac{d\tilde{U}_i}{d\tilde{t}} = \underbrace{\frac{\tilde{u}_i - \tilde{U}_i}{\tau_p}}_{\text{Drag}} + \underbrace{n_g \delta_{i2}}_{\text{Buoyancy}} + \underbrace{n_{th} \frac{\partial \tilde{\theta}}{\partial \tilde{x}_i}}_{\text{Thermophoresis}}. \quad \tau_p = Re \frac{\tilde{d}_p^2}{18C_c} \frac{\rho_p}{\rho_a} \left(1 + 0.15 Re_p^{0.687} \right)^{-1}$$

$$\frac{d\tilde{d}_p}{d\tilde{t}} = \frac{4}{Re Sc_\nu} \frac{\rho_f - \rho_s}{\rho_p} \frac{1}{\tilde{d}_p}, \quad \frac{d\tilde{\theta}_p}{d\tilde{t}} = \frac{12}{Re Pr_p} \frac{1}{\tilde{d}_p^2} \left[\frac{k_v}{k_p} (\tilde{\theta}_f - \tilde{\theta}_p) + \frac{D_v \Delta H_v}{k_p \Delta T} (\rho_f - \rho_s) \right]$$

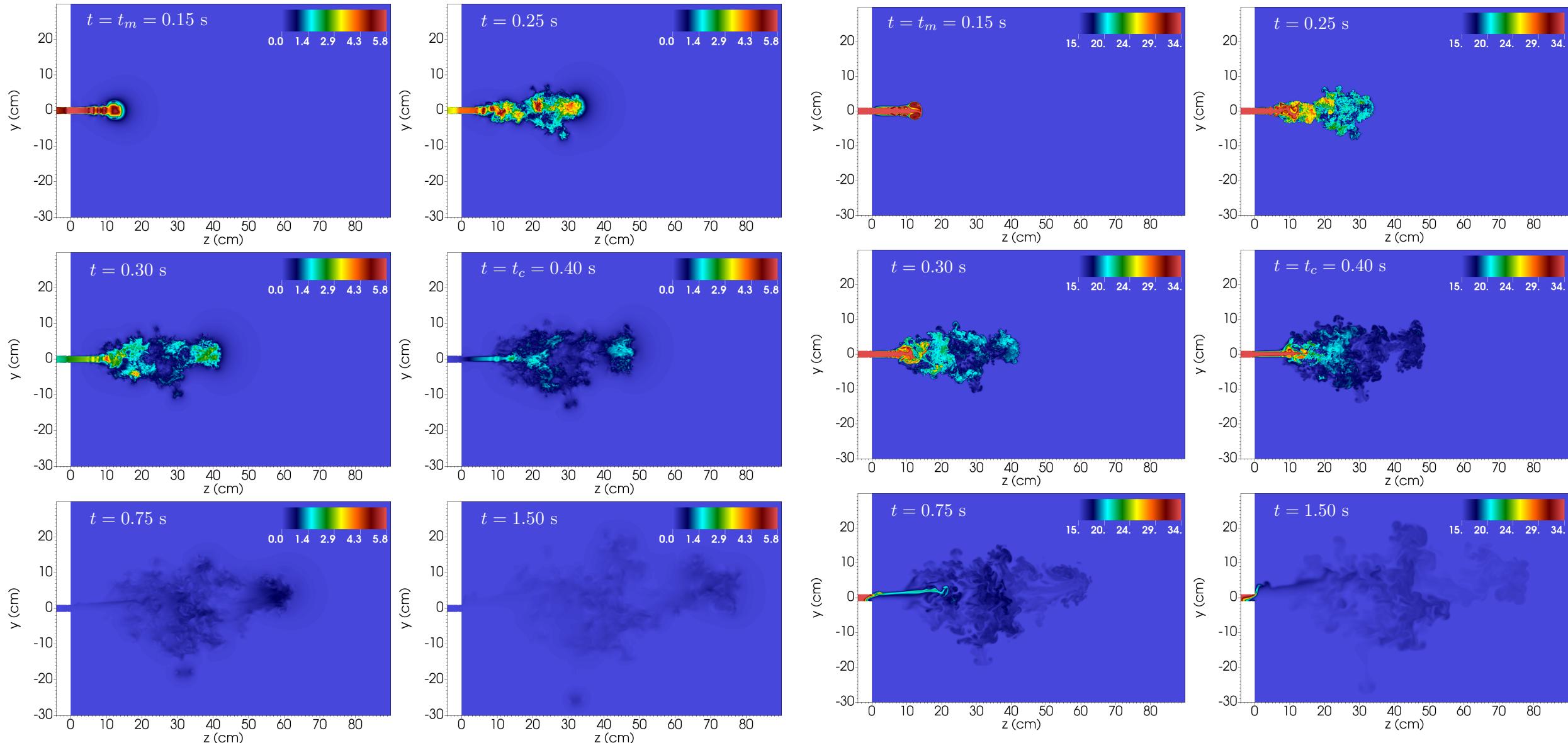
- Spatial discretization using high-order Spectral Element Methods (SEM) [Nek5000]
- 3rd-order semi-implicit time-stepping, *EXT-BDF*
- Current simulation has around 300 million computational points, needing 5.2×10^5 CPU hours
- 4, 8, 16, 32, 64, 128 and 256 micron aerosols
- Evaporative and non-Evaporative
- 200 batches of 69 aerosols
- ~ 200,000 particles

DNS of a small cough (iso-surface of temperature)



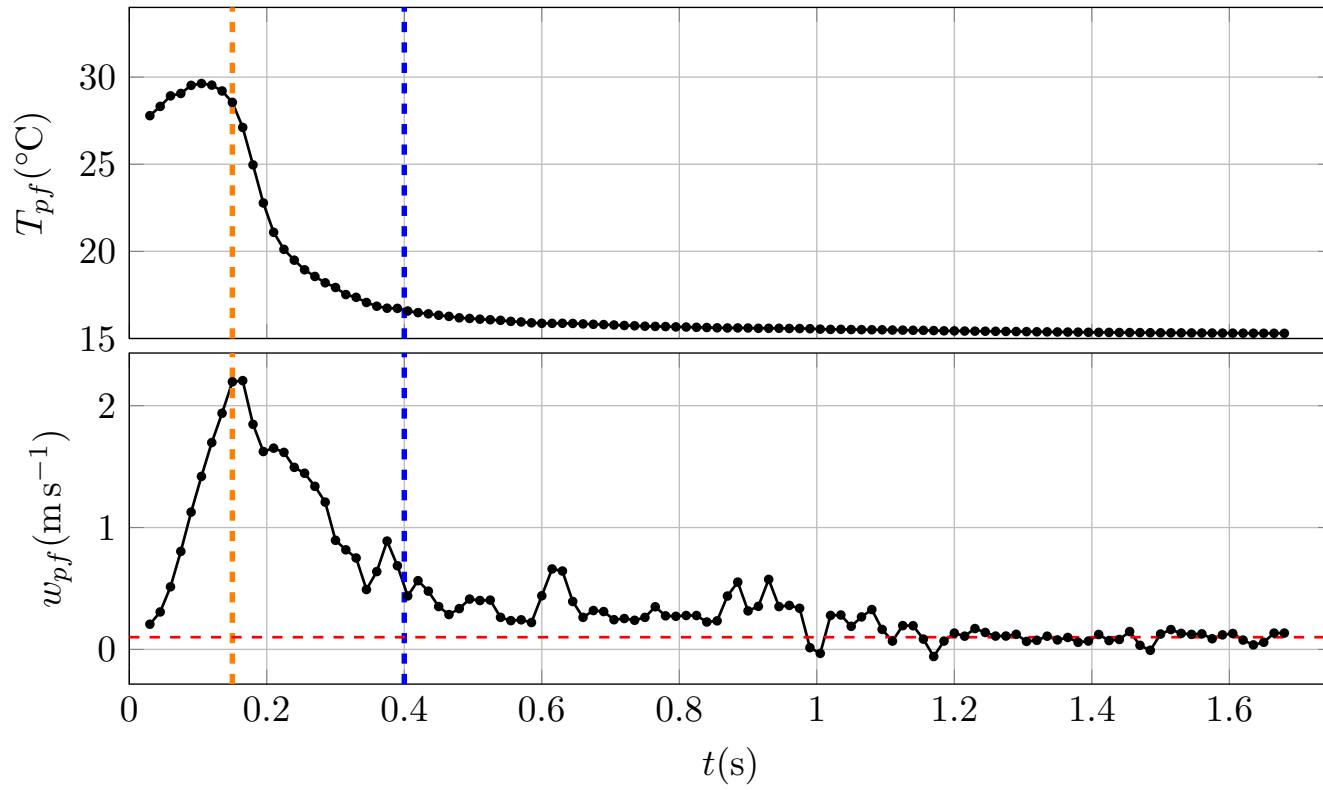
DNS of a small cough

(velocity magnitude [m/s] and temperature [C] of the cough in space and time)

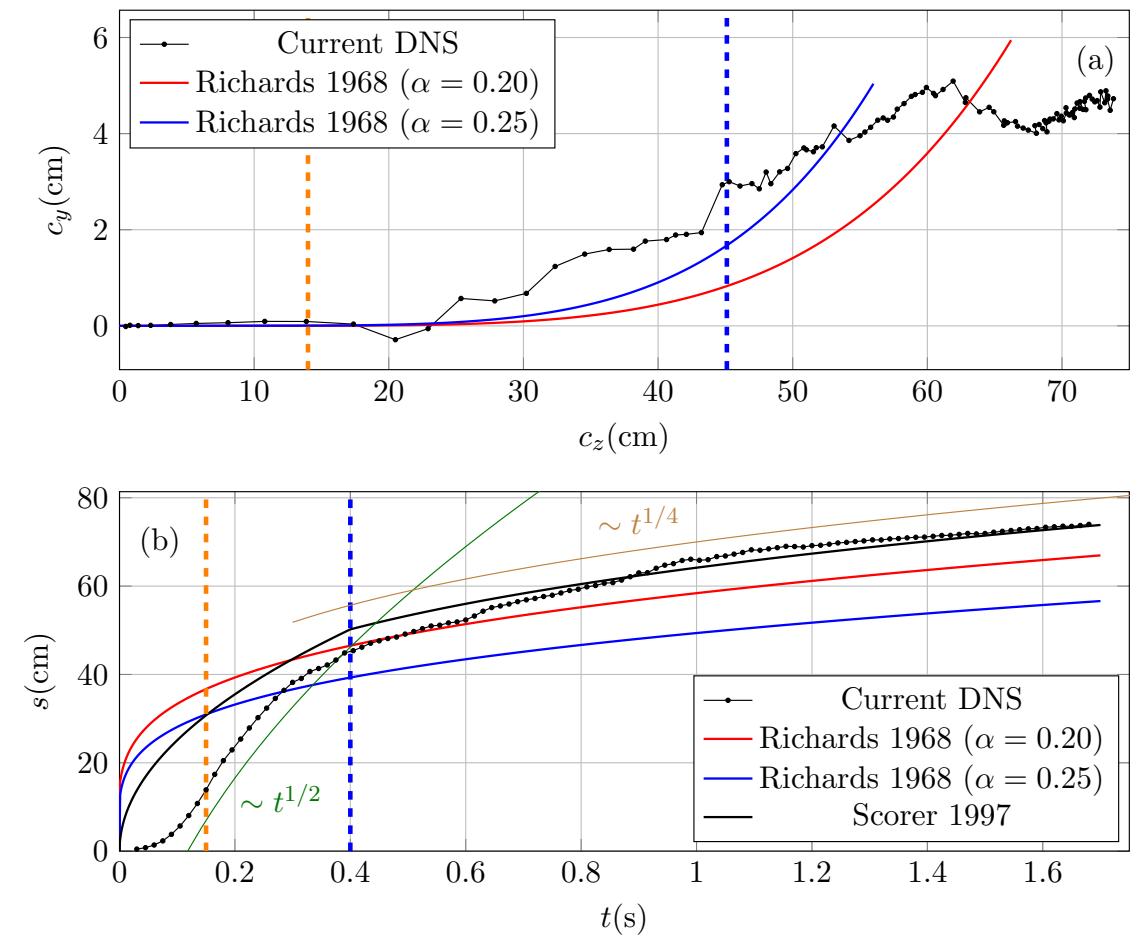


DNS of a small cough

(Puff front evolution and Centroid Location)

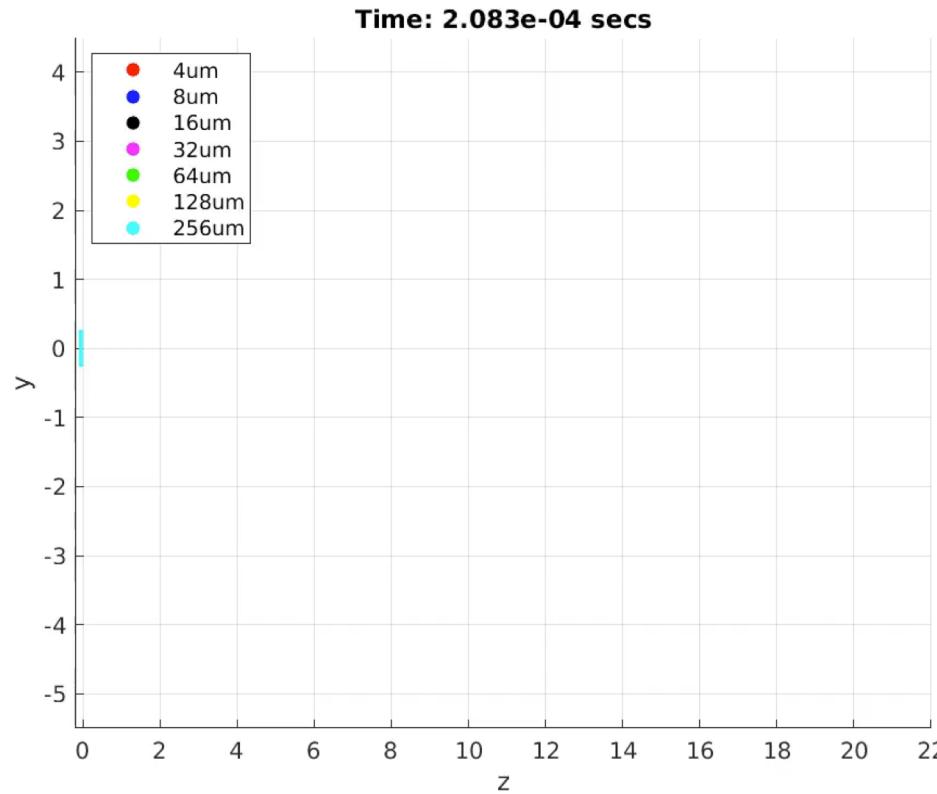


Puff front temperature and vertical velocity

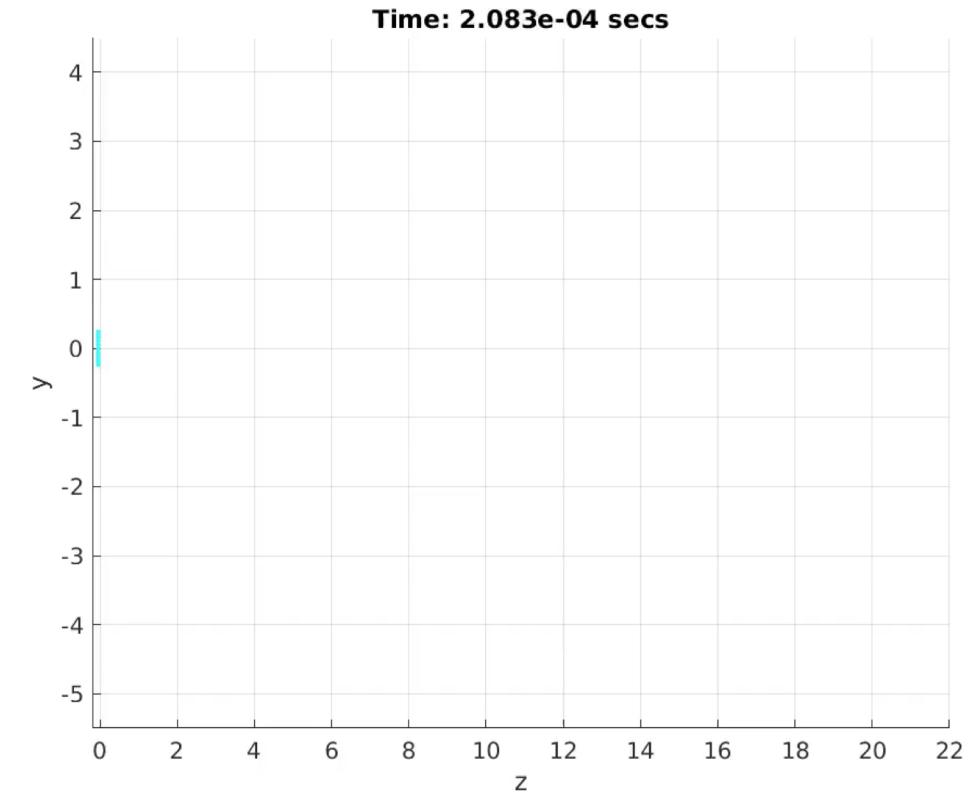


Puff centroid location and time

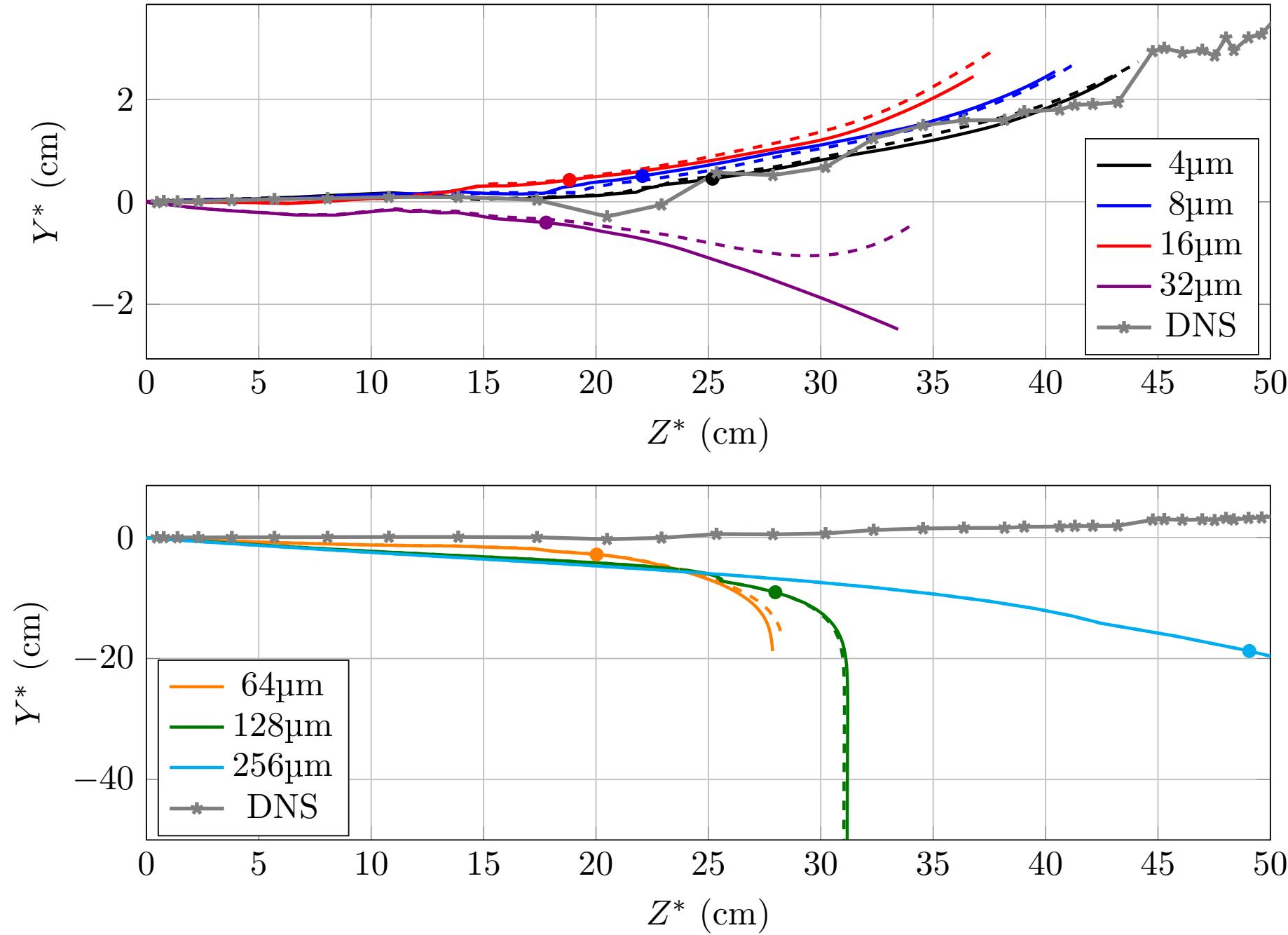
The Dispersed Phase



Non-Evaporating



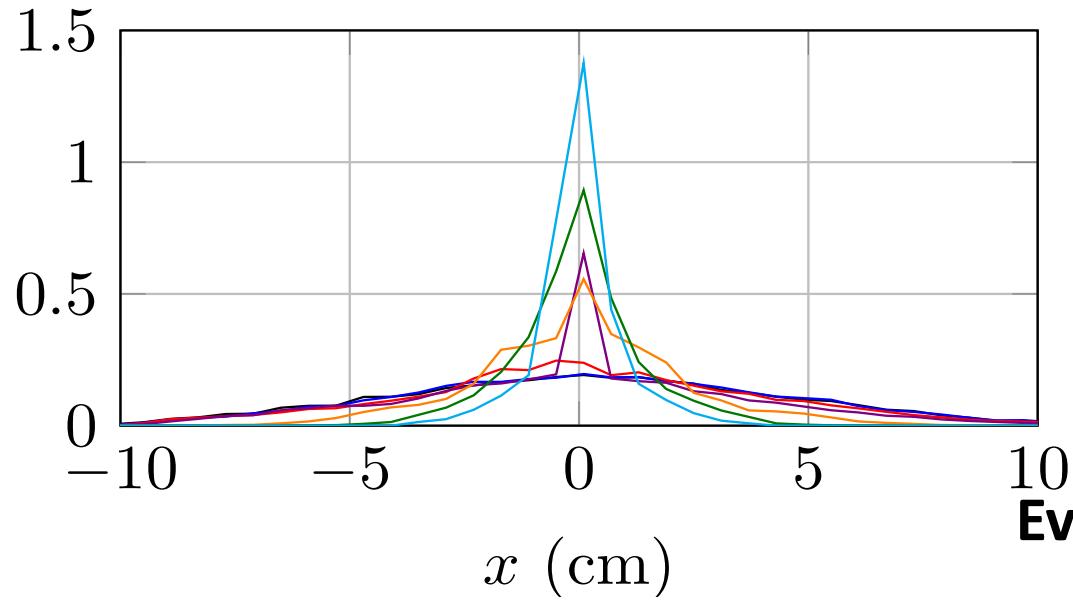
Evaporating



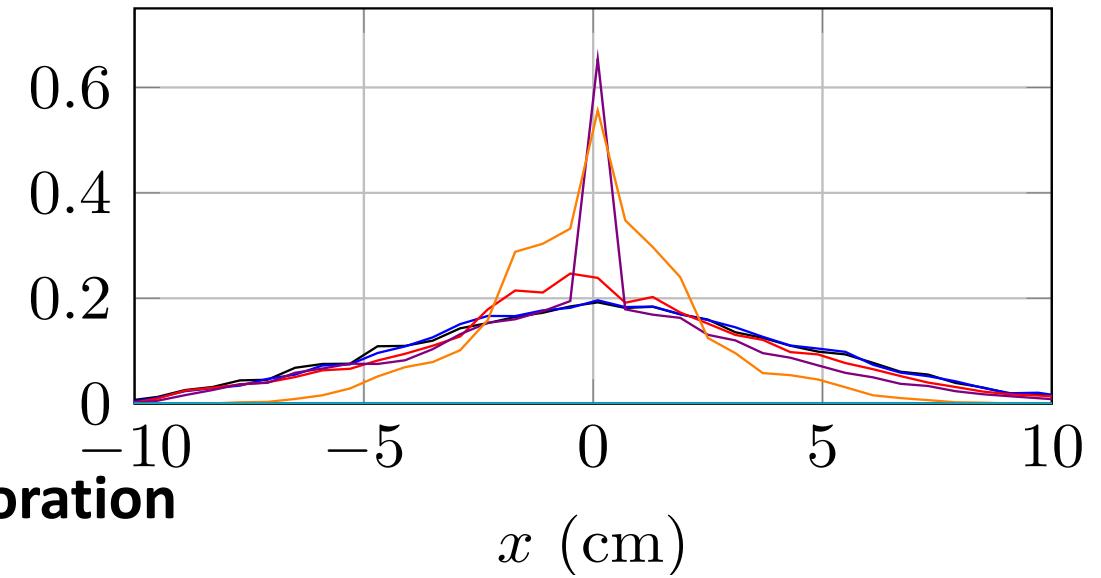
**Dashed –
Evaporation**

**Solid –
non-Evaporation**

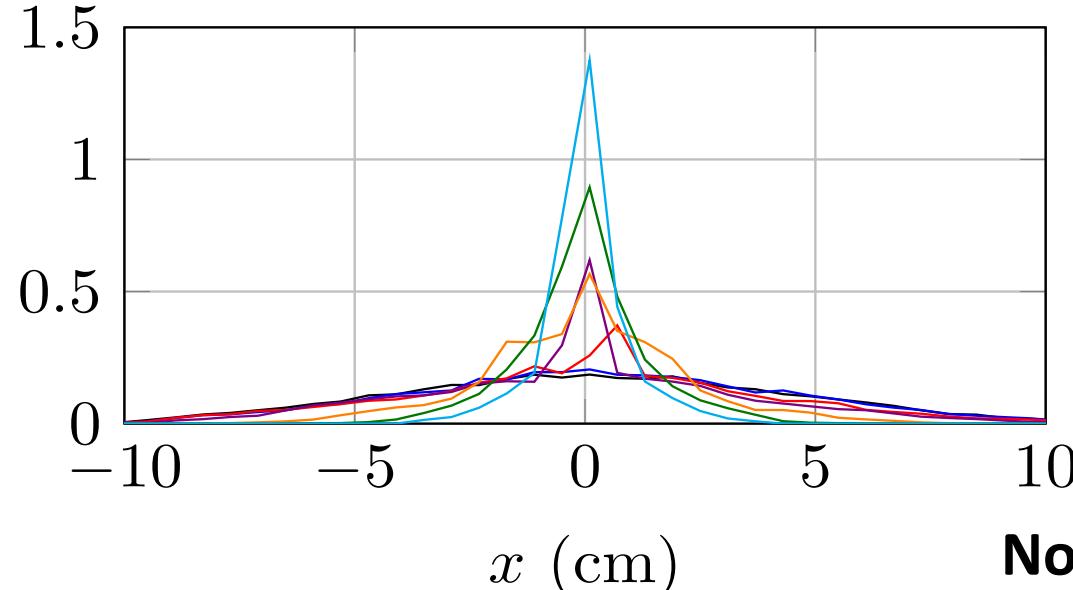
— 4 μm — 8 μm — 16 μm — 32 μm — 64 μm — 128 μm — 256 μm



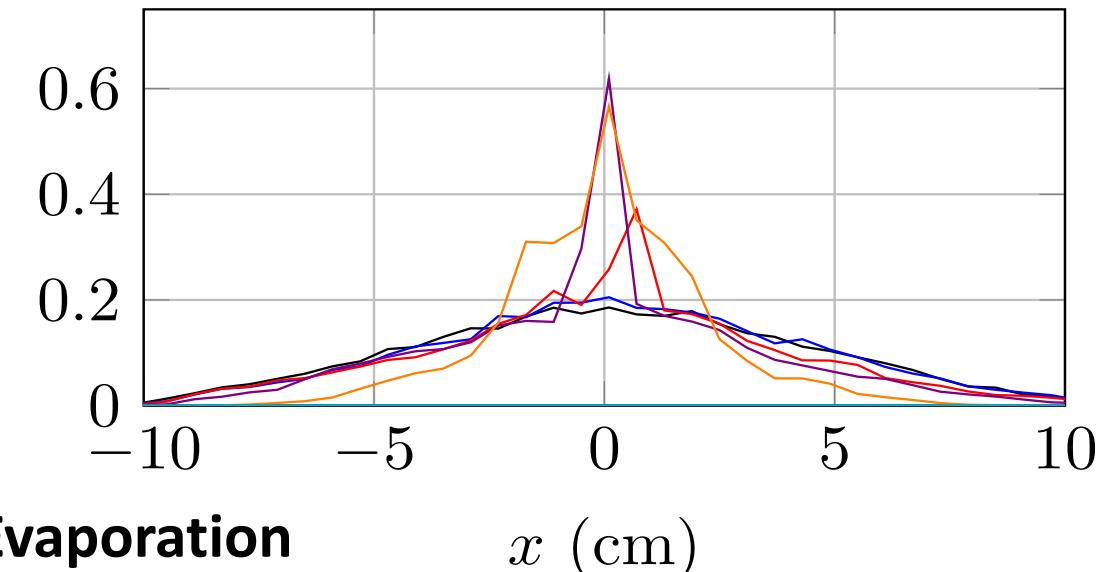
Evaporation



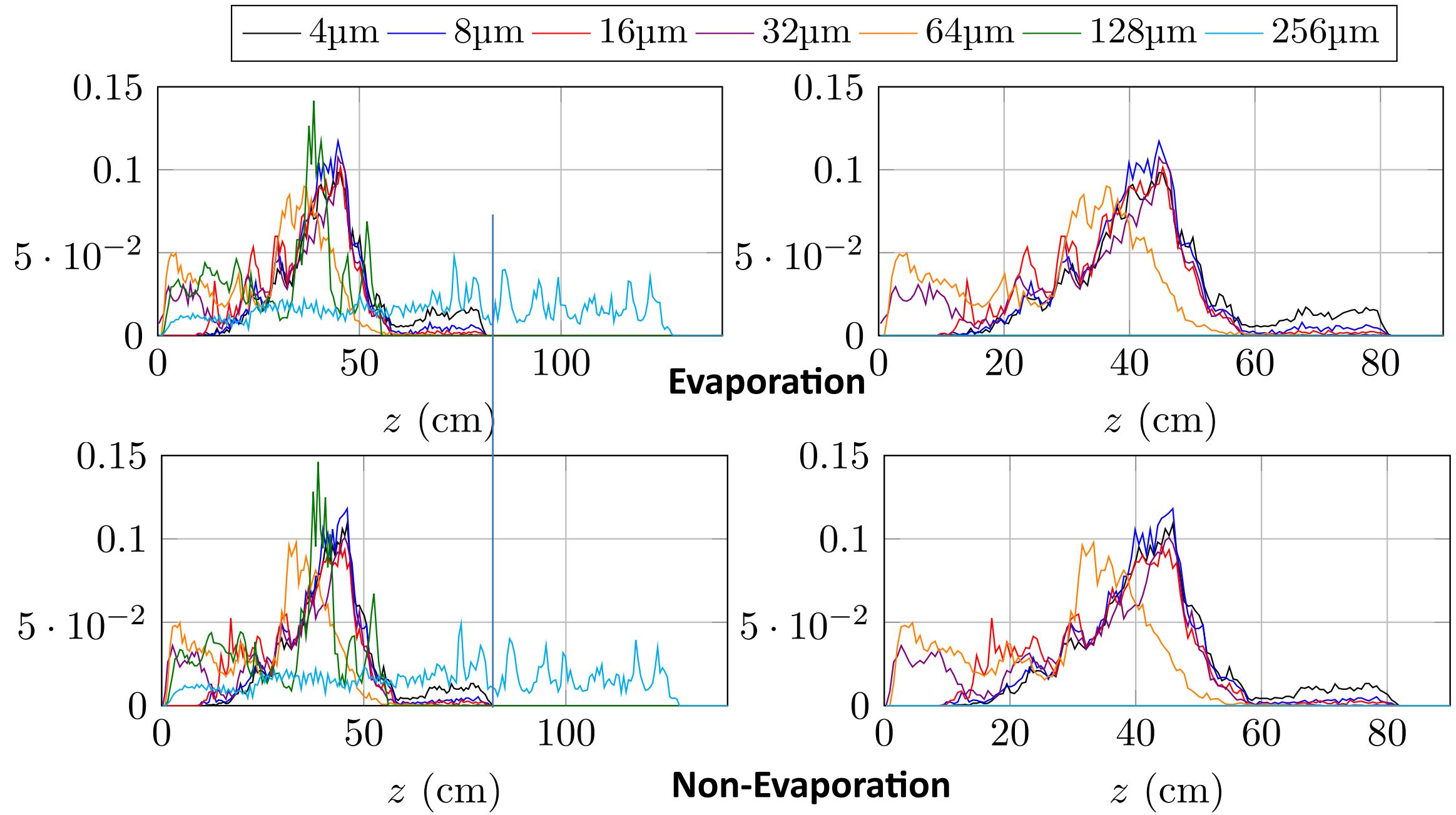
Non-Evaporation



Evaporation

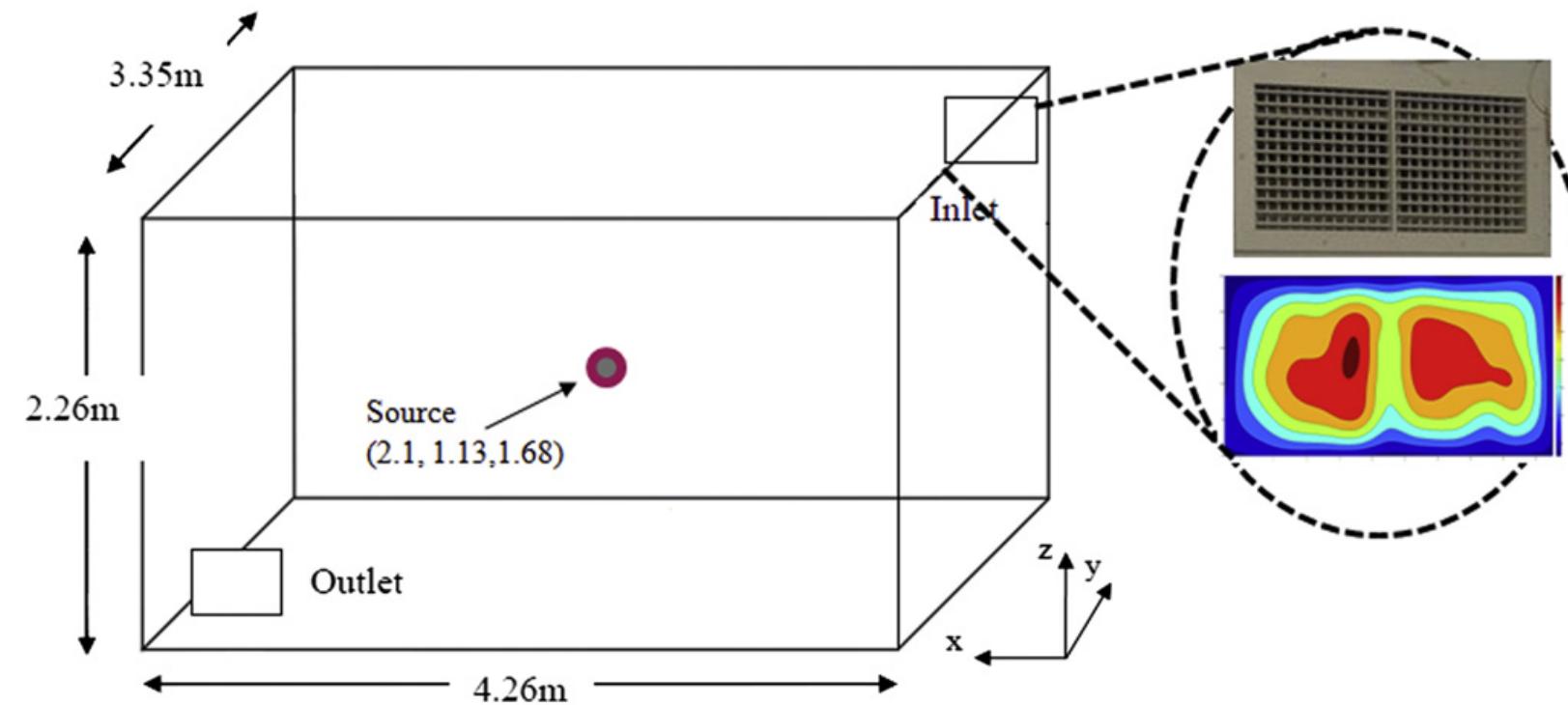


Non-Evaporation

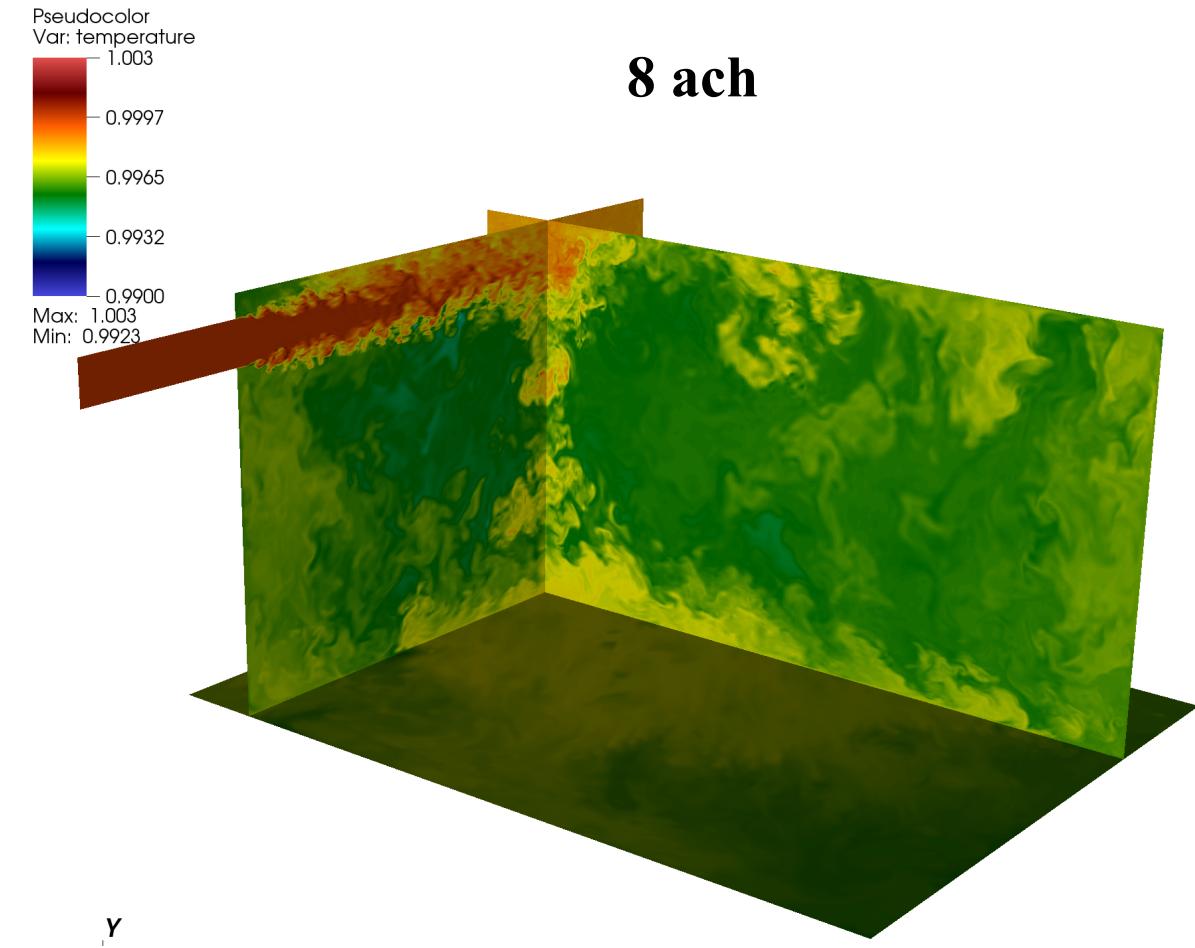
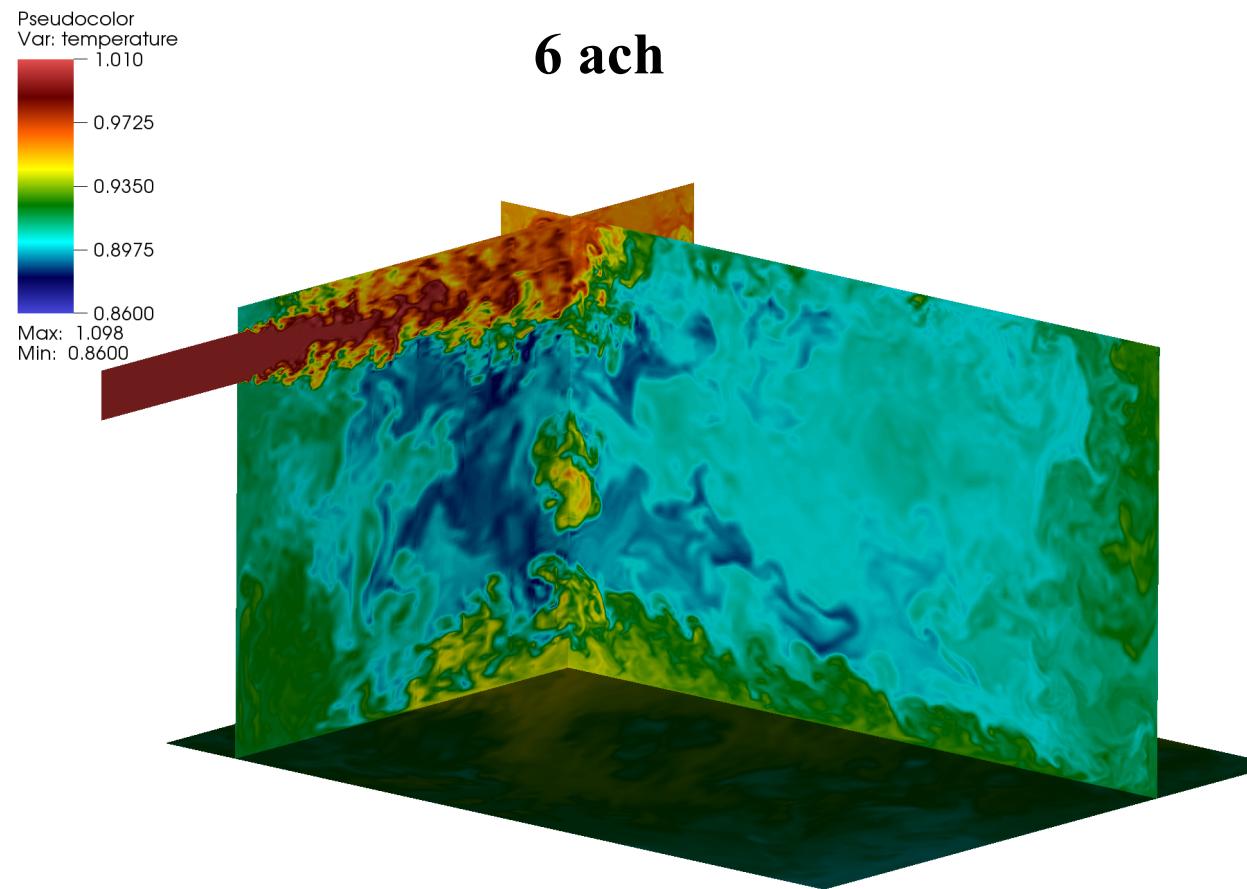


High-Resolution LES of flow and particle transport in a room

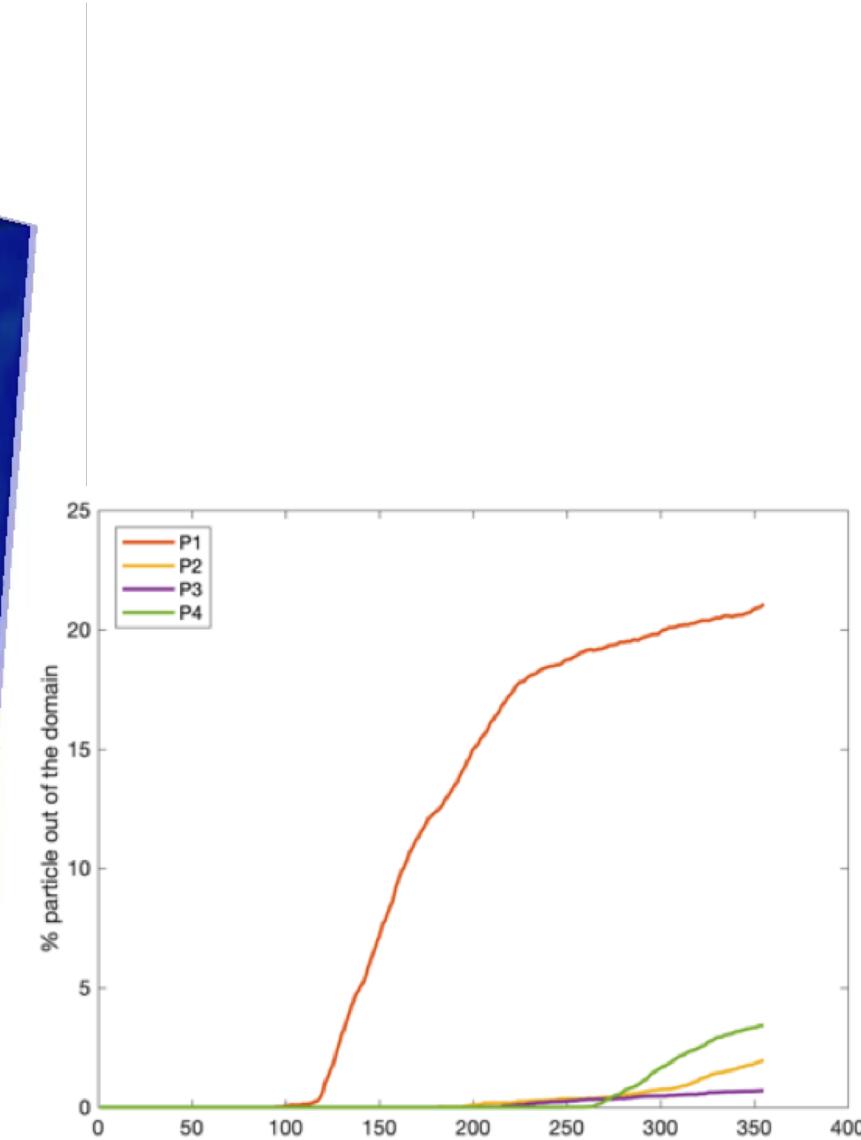
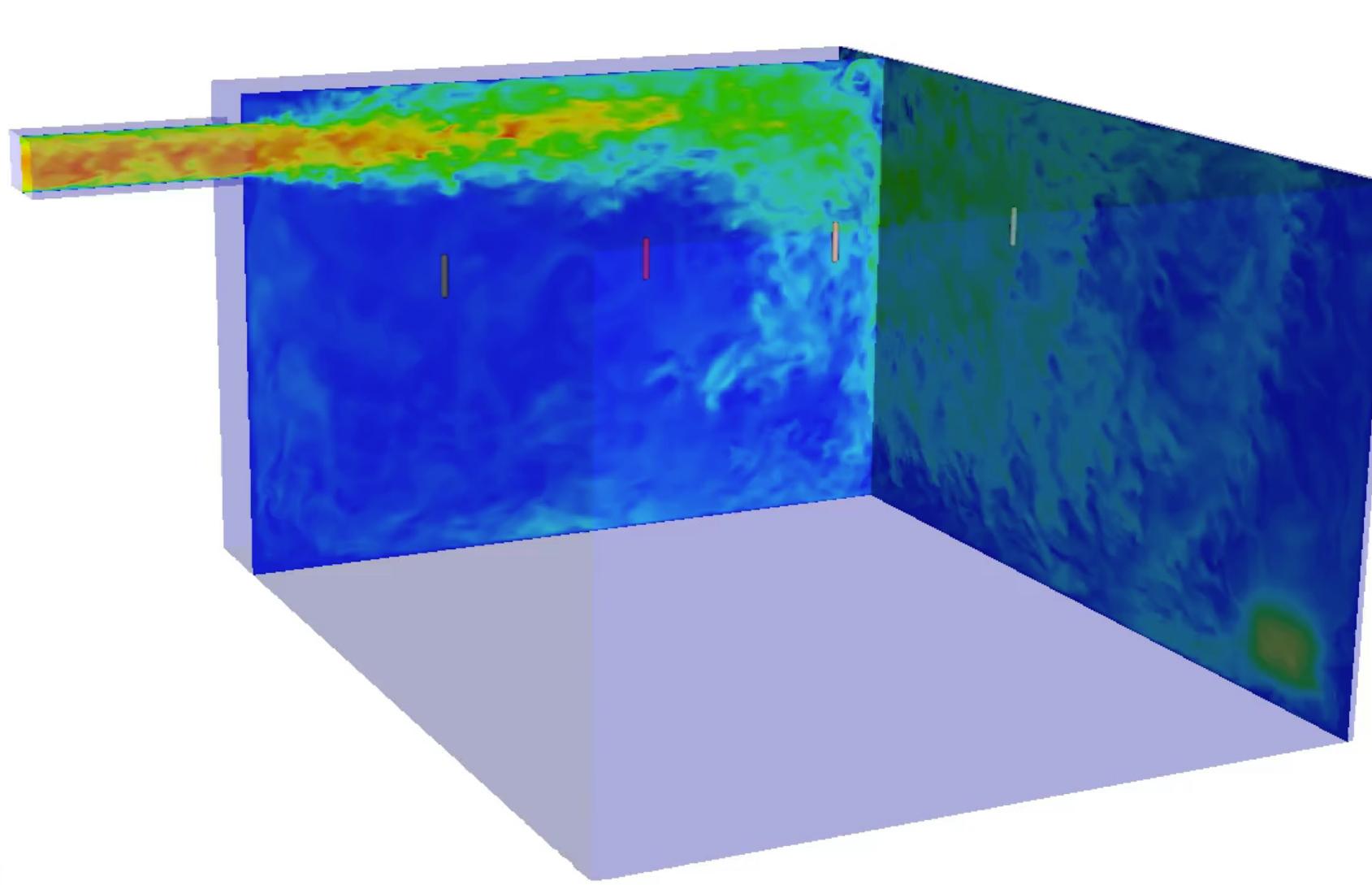
- High-Resolution Large Eddy Simulations (LES) coupled with Lagrangian particle tracking for the aerosols.
- Using high-order Spectral Element Methods for spatial discretization
- Reynolds number: 8000 - 15,000 ~ (4-6-8 ACH)
- Current simulation has 100 million computational points
- 500,000 aerosols (0.5 – 4 -32 microns)
- More expensive, as simulation has to be run longer

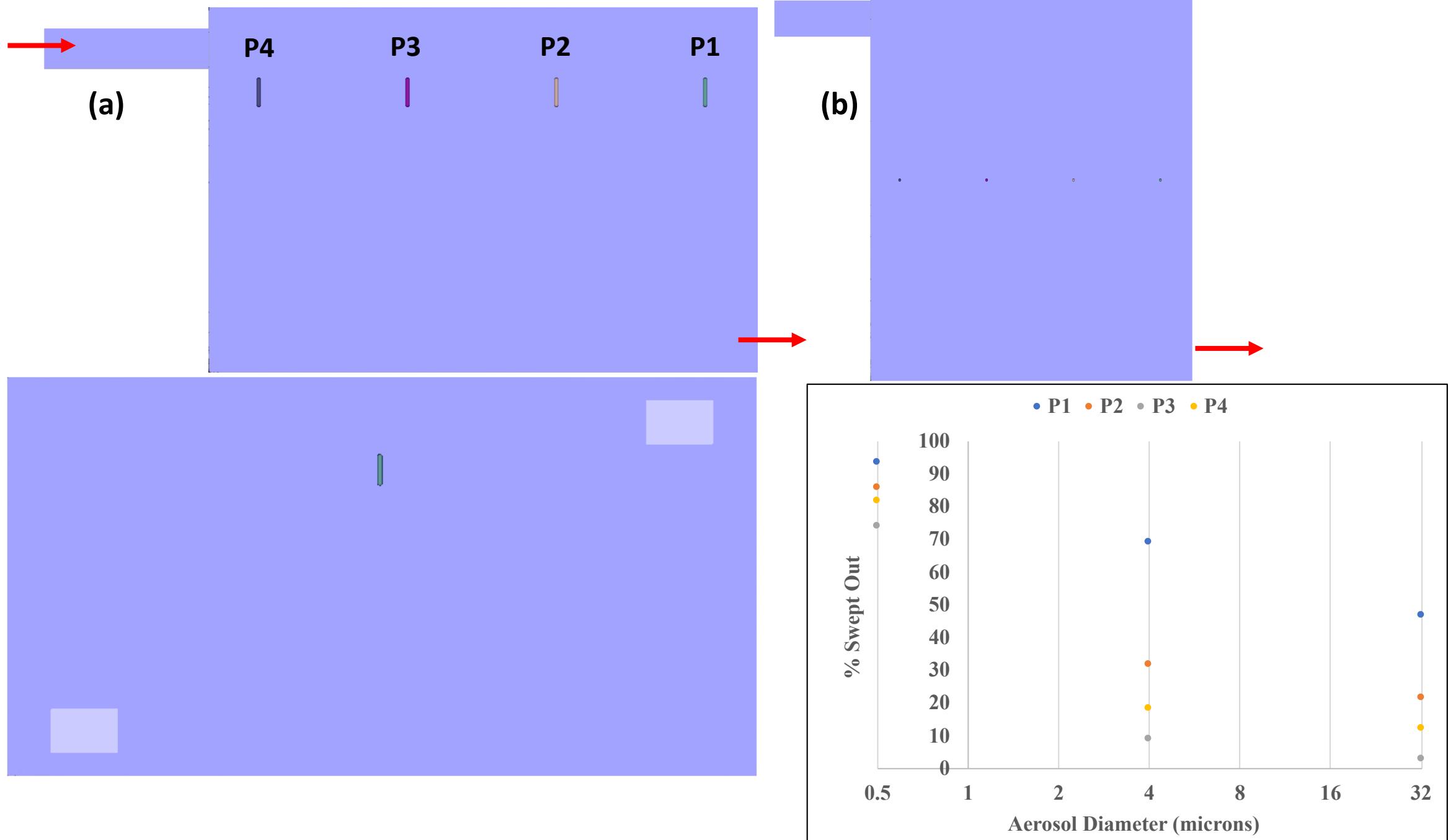


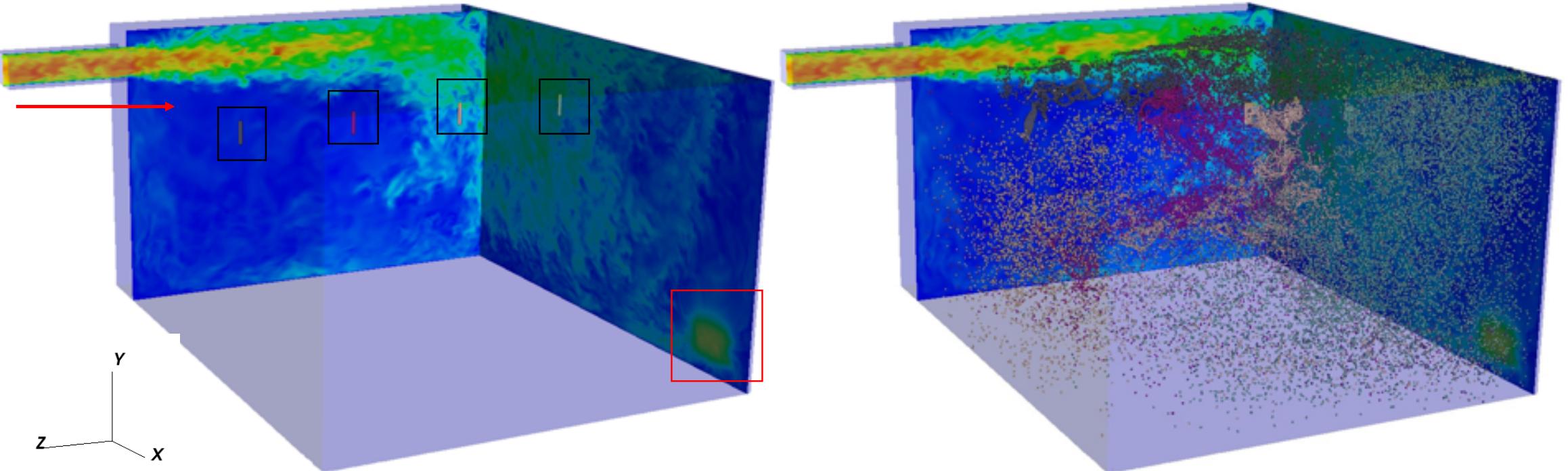
Even in a “simple” Empty room the Mixing Process is Complicated



Difference in Dispersion of Aerosols in the Room Based on Location







- Need substantial time to reach a statistical steady state, before aerosols can be injected
- 1.5 mins of real time takes 768 node hours on Frontera ($\sim 50,000$ cpu hours)
- We need to run for at least $30 - 60$ mins = 31,000 node hours
- Though it takes about 50,000 node hours to reach a statistically steady state, so each simulation of this size is costing about 100,000 node hours

Fast & Accurate Prediction of Virus Loading in Heterogenous Indoor Environments : CEAT

CEAT: The COVID-19 Exposure Assessment Tool (Beta) Company meeting - Scenario A, no masks. Scenario B: 90% wearing KN95 [Save As](#) [signature science](#)

1 Describe the Group

A Group's infection likelihood compared to the community
The Group is composed of people who prior to this activity, you estimate have a likelihood COVID-19 infection that is ...

100 LOWER than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	Scenario A	Scenario B
10 LOWER than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
EQUAL TO the community's average.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
10X HIGHER than the community's average due to their not adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input checked="" type="checkbox"/>	<input type="checkbox"/>
100 PERCENT since they are known to be infected with COVID-19.	<input type="checkbox"/>	<input checked="" type="checkbox"/>

B Group's vaccination rate: 100 % Check here to apply Group's Vaccination Rate to the Exposure Calculations

C Group members use of viral genome or protein surveillance testing
 All members are tested within 3 days prior to event All unvaccinated members are tested within 3 days prior to event Testing not required or testing status unknown

2 Number of People
Number of People Sharing Activity Space (Must be between 2 and 250)
Scenario A: 30 Scenario B: 30

3 Distance Between People (meters)
Either enter distance below...
Or select a distance.
Scenario A: 0.75 Scenario B: 0.75

4 Mask Type and Percent Wearing Masks
Mask Type Scenario A Scenario B
Fitted N95
K95/KN95
Double-Surgical Mask
Surgical Mask
Average Mask
Cloth Mask
No Mask
% of People Wearing Masks Scenario A Scenario B
100%
90%
75%
50%
25%
0%

5 Vocalization Intensity
Resting Scenario A: Scenario B:
Standing Scenario A: Scenario B:
Light Exercise Scenario A: Scenario B:
Heavy Exercise Scenario A: Scenario B:
Speaking Scenario A: Scenario B:
Loudly Speaking Scenario A: Scenario B:
Singing Scenario A: Scenario B:
Loudly Singing Scenario A: Scenario B:
Shouting Scenario A: Scenario B:
Loudly Shouting Scenario A: Scenario B:
Screaming Scenario A: Scenario B:
Loudly Screaming Scenario A: Scenario B:

6 Breathing Rate
Select Breathing Rate
Sleep Resting Light Activity Moderate Exertion Heavy Exertion
Scenario A
Scenario B

7 Duration of Activity
Duration of Activity in Hours (Must be between 0.08 hr [5 min] and 12 hr)
Scenario A: 3.00 Scenario B: 3.00

8 Indoors or Outdoors
Scenario A: Outdoor Indoor Scenario B: Outdoor Indoor
A For Outdoor Activities: Select Wind Conditions
Moderate (21–29 km/h) Raises dust and loose paper, small branches are moved
Gentle (13–19 km/h) Leaves/small twigs in constant motion, wind extends light flag
Light (6–11 km/h) Wind felt on face, leaves rustle
Calm (2–5 km/h) Direction of wind shown by smoke drift
Very Calm (0.8–1.5 km/h) No direction or flow observed
B For Indoor Activities: Enter indoor ACH (Air Changes/Hour)
• ACH can be acquired from building engineers or H&S
• Alternatively, select an ACH value from Table to the right
• AER (Air Exchange Rate) is another name for ACH
Scenario A: 3.00 Scenario B: 3.00

C Room Filtration
Filter Efficiency Scenario A Scenario B
HEPA Filters 95%
MERV 13 80%
MERV 8 50%
No Filters 0%

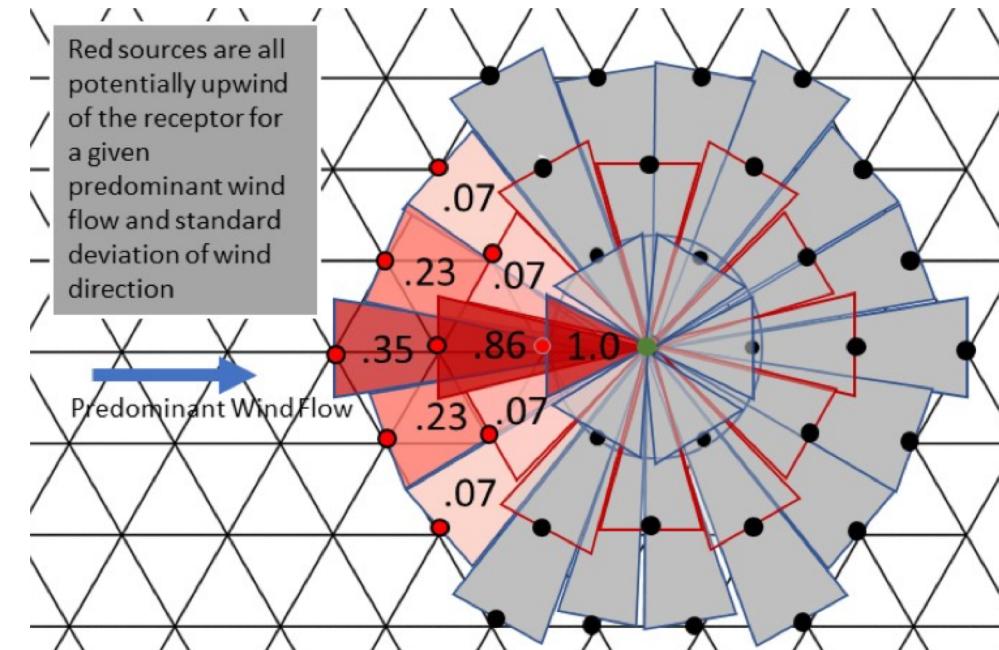
9 If Indoors, Room Dimensions
Room Length (m) Scenario A: 12.0 Scenario B: 12.0
Room Width (m) Scenario A: 12.0 Scenario B: 12.0
Ceiling Height (m) Scenario A: 3.00 Scenario B: 3.00
Room Area (m²) Scenario A: 144.96 Scenario B: 144.96
Room Volume (m³) Scenario A: 434.88 Scenario B: 434.88
MEASURE YOUR ROOM

10 Adjustments to Current Local Conditions
Average Daily Cases per 100,000 in the last week: 230.00 Average Days Infectious (Set to 5 if unknown): 5.00 Undiagnosed Factor for Area (Set to 3 if unknown): 3.0 Active Infections per 100,000: 3,402.7
Variant Prevalence Comparative Increased Transmission versus Wild-Type Virus (%) Immunity Prevalence
WHO Variant Name Estimate of Active Infections (%) Scenario A Scenario B
Alpha 0.0 0.0 70.0 %
Beta 0.0 0.0 32.0 %
Delta 20.0 100.0 Effectiveness of Immunity 37.0 %
Omicron 80.0 980.0 Correlation Factor Poisson Distribution Adjustment Factor 0.60
Disclaimer Statement: By using this tool you agree to be bound by this disclaimer. This tool does not provide a prediction of the likelihood of infection or transmission of disease, nor does it provide advice or guarantee outcome. It solely provides a means for the user to estimate theoretical relative exposure. It is intended for informational purposes only and users should not rely on output for decision-making. Information is gathered from various sources and Signature Science, LLC, COV-IRT or its members are not responsible for errors or omissions in data. No warranties are given in relation to this tool and it is not guaranteed as fit for purpose.

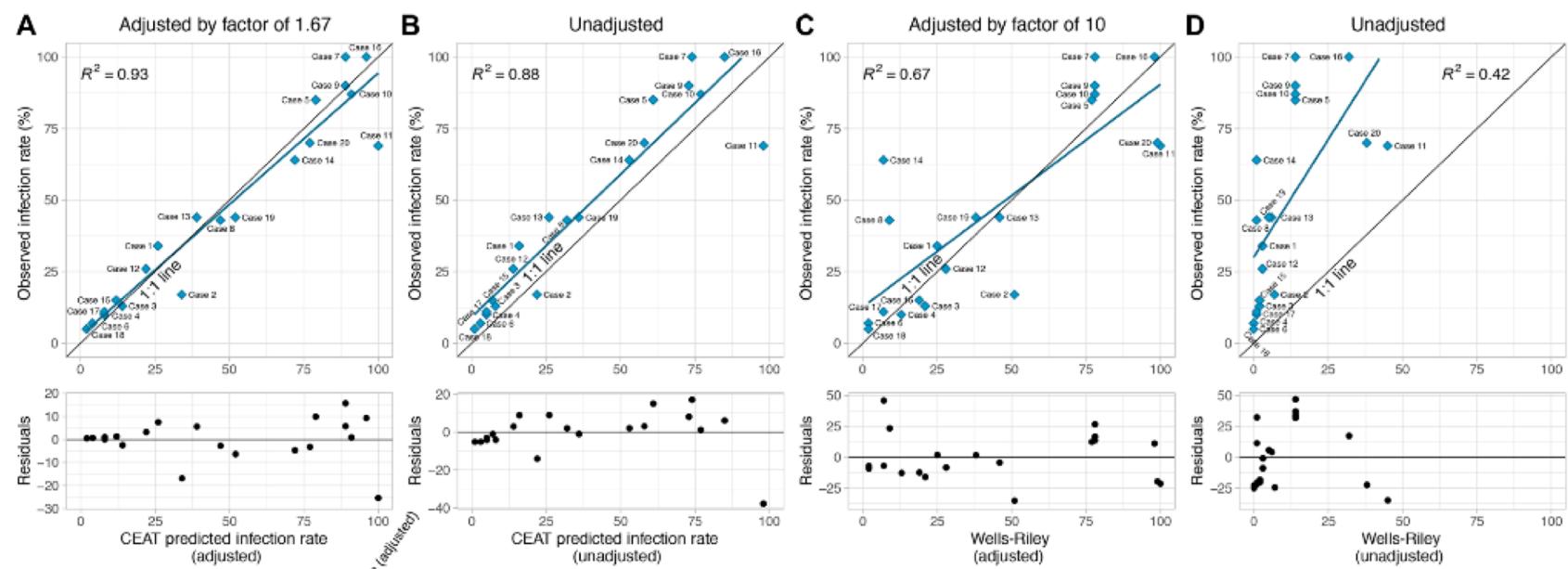
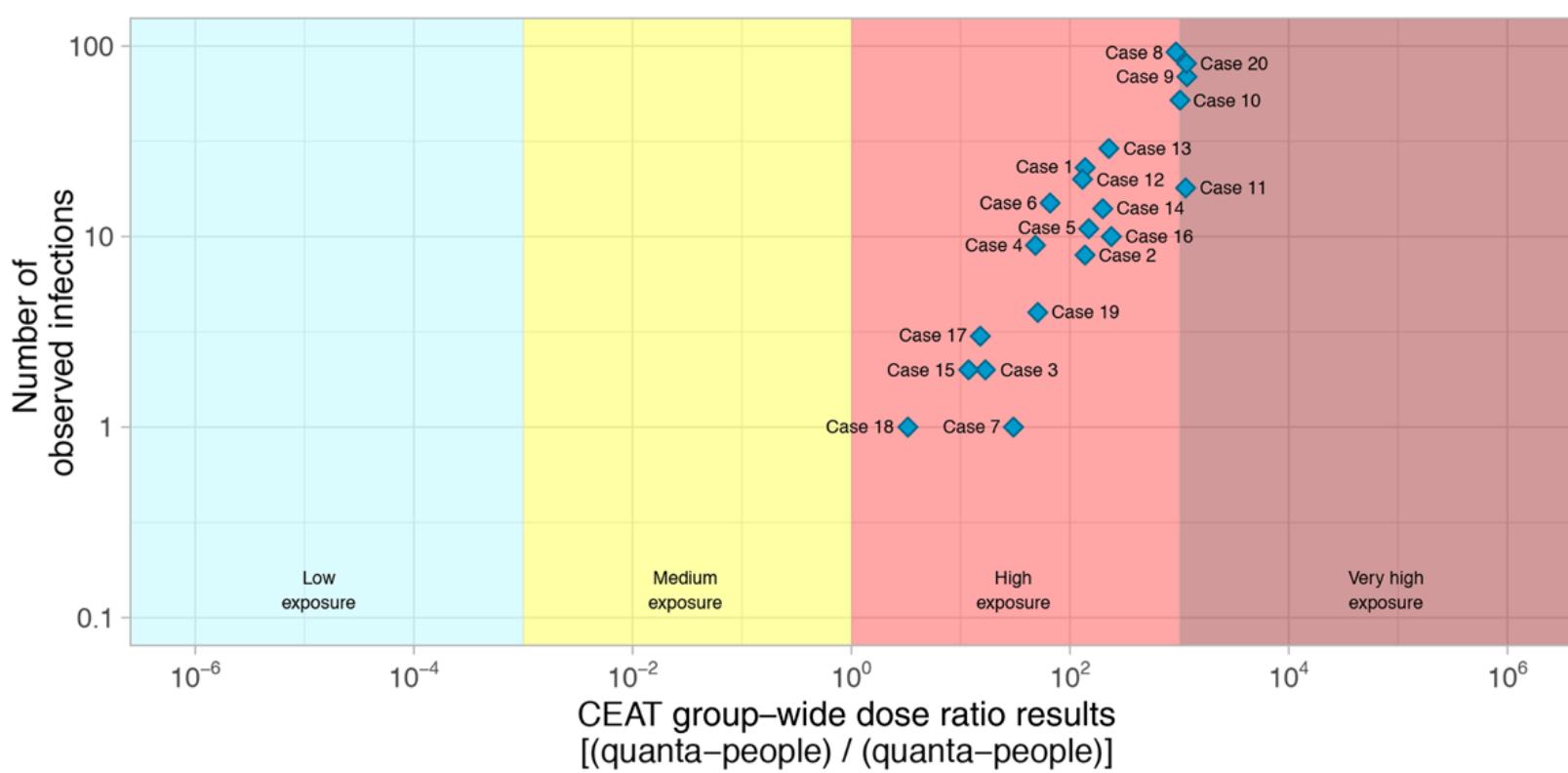
ACH VALUES
Medical General 6 Education Classrooms (Ages 5 To 8) 2 Manufacturing Manufacturing Floor 1.5
Laboratory 6 Classrooms (Ages 9 +) 2 Residential Homes with Closed Windows 0.5
Treatment Room 6 Daycare (Through Age 4) 2.5 Homes with 1 Open Window 1.75
Examination Room 6 Homes with All Open Windows 3 Lecture Hall (Fixed Seats) 7
Retail Sales (Except as Noted Below) 1.5 Library 1.5 Lecture Classroom 3
Barber shop 3.75 Hair and Nail Salons 3.75 Libraries 1.5
Supermarket 0 Office 0.5 Music/Theater/Dance 2.5
Food Court 2-6 Gym 0.5 Travel Aircraft 20
Bars 2-6 Reception Area 1.25 Train 6
Restaurants 2-4 Meeting/Conference Rooms 2 Bars 6
Homes with Open Windows 6
Cars (Windows Closed) 6
Cars (Windows Open) 10

RESULTS
Lower Exposure Medium High Very High
Scenario A
Scenario B
0.00001 .00001 .0001 .001 .1 1 10 100 1,000 10,000

To Reduce Exposure
Group-wide Exposure Ratio: Scenario A: 1394.07 Scenario B: 3.4851!
Individual Exposure Ratio: Scenario A: 106.87! Scenario B: 0.2671!
Individual Dose (Quanta): Scenario A: 4.7186! Scenario B: 0.01171!
Infection Rate (%): Scenario A: 99.961! Scenario B: 1.9468!
Number of Index Infectors: Scenario A: 1.0005 Scenario B: 1.0005!



CEAT's ability in predicting Super Spreader Events



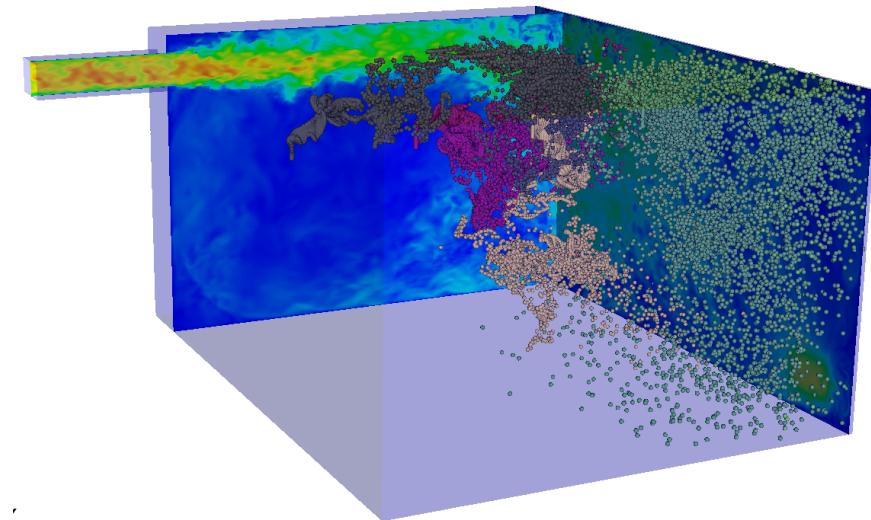
Can we Improve the Computational Performance using GPUs ? (NekRS)

- Tests run on 10 nodes of Summit (60 GPUs)
- With a uniform distribution of particles
- **Migration** (Yes/No): Exchanges particle ownership so that each process owns the particles that are present in its elements. (using a fast all-to-all data exchange using *crystal router*)

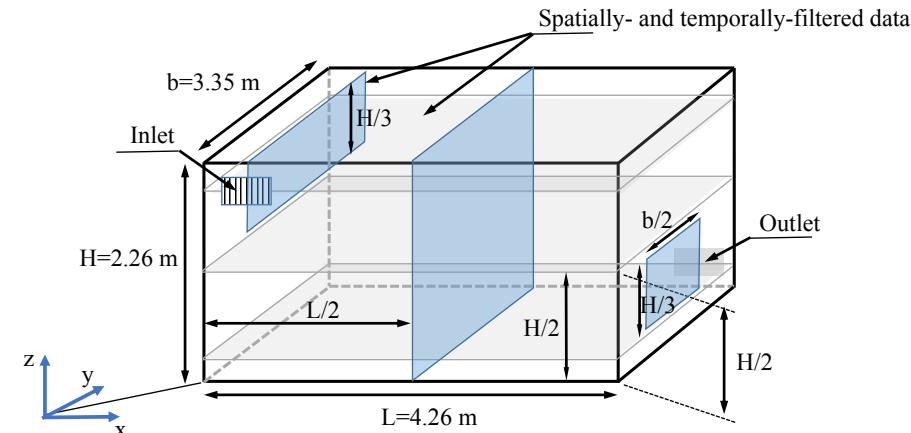
Findpts implementation Migration particle count	GPU						CPU			
	Yes			No			Yes		No	
	100 ³	150 ³	200 ³	100 ³	150 ³	200 ³	100 ³	150 ³	100 ³	150 ³
Fluid Solve	98.2	98.1	98.5	99.2	98.2	107.5	97.9	98.7	101.2	100.1
Particle Creation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Particle Update	3.6	8.5	19.1	18.6	60.8	146.1	277.0	910.2	288.3	953.9
- Copy fluid vel. to host	-	-	-	-	-	-	15.7	13.9	16.4	15.5
- findpts	2.7	6.4	14.3	8.9	29.0	69.1	225.3	746.5	234.1	775.9
- - Memcpy	0.4	0.7	1.2	0.8	1.8	4.2	-	-	-	-
- - Kernel	1.8	4.9	11.3	1.9	6.4	14.6	219.7	735.7	220.4	734.7
- migration	0.1	0.1	0.3	-	-	-	0.1	0.2	-	-
- findpts_eval	0.6	1.3	3.1	9.4	31.0	74.9	49.7	158.5	54.0	177.1
- - Memcpy	0.2	0.4	0.9	0.3	1.0	2.0	-	-	-	-
- - Kernel	0.5	0.9	2.2	0.3	0.8	1.4	49.6	158.5	43.2	141.9
- Advance position	0.2	0.5	1.2	0.2	0.5	1.3	0.2	0.5	0.1	0.5
- Barrier	0.0	0.1	0.2	0.1	0.3	0.8	1.8	4.4	0.1	0.3

Conclusions and Future Directions from Room-scale Simulations

- We are conducting some of the first high-fidelity turbulence resolved simulations of aerosol transport in indoor environment.
- These simulations will be used as benchmark results to compare/improve lower-fidelity models (e.g. RANS based)
- Improved understanding of effect of aerosol size, release location, air-flow rates and evaporation on residence time and deposition pattern of virus-laden aerosols
- The high-resolution model results are being used to analyze and understand the large and small scale turbulent structure of the flow



Basic Measurement Setup



Temporal states: Development and Stationary

Final Objective: Development of a robust Covid-19 Exposure Assessment Tool (CEAT)

Part Step 1 Enter information that describes the Group.

Group's Infection Likelihood compared to the Community

The Group is composed of people who, prior to this activity, you estimate have a likelihood COVID-19 infection that is...

0x lower than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.
0x lower than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people. equal to the community average.

0x higher than the community's average due to their not adhering to public health guidance on distancing, masking, and exposures to crowds. 00 percent, since they are known to be diagnosed with active COVID-19.

Group's Vaccination Rate: 100.00 % Click to apply Group's Vaccination Rate to the Exposure Calculations

Group members use of viral genome or protein surveillance testing

All members are tested within 3-days prior to event All unvaccinated members are tested within 3-days prior to event Testing not required (or testing status unknown)

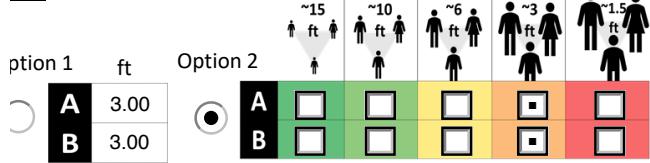
Step 2 Enter the number of people sharing the space for the activity.

Must be between 2 and 250 people.

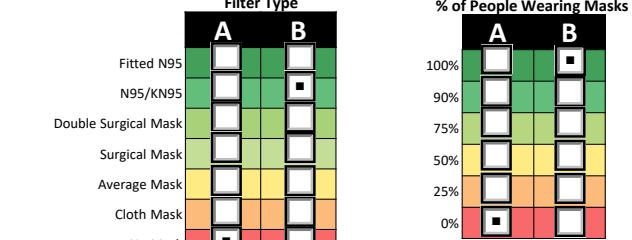
Number of People Sharing Activity Space:

A 10 B 10

Step 3 Enter distance (Option 1) or select distance (Option 2)



Step 4 Select Mask Type and Prevalence of mask wearing



Step 5 Select Vocalization Intensity

Step 6 Select Breathing Rate

Activity Exhalation Type A B

Step 7 Enter the duration that most closely matches activity.

Duration of Activity in Hours: A 1.00 B 1.00

Step 8 Select whether outdoor or indoor

a. Outdoor: A: B: **Outdoor activities:** Select wind conditions that best match.

Beaufort Scale		A	B
Moderate	13 - 18 mph	Raises dust and loose paper; small branches are moved	<input type="checkbox"/>
Gentle	8 - 12 mph	Leaves/small twigs in constant motion. wind extends light flag	<input type="checkbox"/>
Light	4 - 7 mph	Wind felt on face, leaves rustle	<input type="checkbox"/>
Calm	1 - 3 mph	Direction of wind shown by smoke drift	<input type="checkbox"/>
Very Calm	0.1 - 1 mph	No direction or flow observed	<input type="checkbox"/>

b. Indoor: A: B:

Obtain the Air Changes per Hour (ACH) using Option 1 or 2:

- Option 1 – Use ACH provided by building engineers or H&S.
- Option 2 – from Table 1 on right, select the facility type and ACH that best matches the activity location.

Enter indoor ACH (or AER¹) Values:

Indoor ACH A 6.00 B 6.00

¹ ACH (Air Changes per Hour) is synonymous with AER (Air Exchange Rate [Exchanges/Hour])

c. Room Filtration

Select Flowrate Option:

Flow Option 1 – Use a default assumption of flow of filtered air of 1 cfm/ft².

Flow Option 2 – Enter a specific filtration flow rate if known

HEPA Filters	A	B
MERV 13	<input type="radio"/>	<input type="radio"/>
MERV 8	<input type="radio"/>	<input type="radio"/>

Table 1: Typical ACH Values (Option 2)

Facility Type	ACH
Medical General	6
Laboratory	6
Treatment room	6
Examination room	6
Retail Sales (except as below)	1.5
Barbershop	1.5
Hair and nail salons	3.75
Supermarket	1
Fast Food	6
Bars	2-6
Restaurants	2-4
Education Classrooms (ages 5 to 8)	2
Classrooms (age 9 plus)	2
Daycare (through age 4)	2.5
Multilevel assembly	5
Lecture hall (fixed seats)	7
Lecture classroom	3
Libraries	1.5
Music/theater/dance	2.5
Office Office space	0.5
Reception Area	1.25
Meeting/ Conference Rooms	2
Manufacturing Manufacturing Floor	1.5
Residential Homes with closed windows	0.5
Rooms with one open window	1.75
Homes with all open windows	3



CEAT COVID-19 Exposure Assessment Tool

US Customary Units (US)
23 January 2022 V B.34_US BETA

Step 10 Calculate Adjustment to Local Community's Current Conditions

Average Daily Cases per 100,000 in the Last Week → Average Days Infectious (Set to 5 if not known) → Undiagnosed Factor for Area (Set to 3 if not known) → Active Infections per 100,000² = 909.2

WHO Variant Label	Estimate of Portion of Active Infections (%)	Comparative Increased Transmission versus Wild-Type Virus (%)	Immunity Prevalence
Alpha	0.00	0.00	Population Vaccination Rate (%) 65.00
Beta	0.00	0.00	Population Recovered (%) 35.00
Delta	2.00	100.00	Protection Effectiveness of Immunity (%) 37.00
Omicron	98.00	940.00	Correlation Factor Poisson Distribution Adjustment Factor 0.60

Results

Group-wide Exposure Ratio													
Lower Exposure		Medium	High	Very High									
A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>									
B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>									
	.000001	.00001	.0001	.001	.01	.1	1	10	100	1000	10,000	100,000	
A	Group-wide Exposure Ratio: 2.250570	Group-wide Exposure Ratio: 0.045011											
B	Group-wide Exposure Ratio: 2.079561	Group-wide Exposure Ratio: 0.171008	Group-wide Exposure Ratio: 0.041591	Group-wide Exposure Ratio: 0.003420									
	Individual (Indv.) Exposure Ratio: 0.450114	Individual (Indv.) Exposure Ratio: 0.009002	Individual (Indv.) Exposure Ratio: 0.0003	Individual (Indv.) Exposure Ratio: 0.0651									
	Indv. Dose (Quanta): 0.0196	Indv. Dose (Quanta): 3.2261	Indv. Dose (Quanta): 0.0003	Indv. Dose (Quanta): 0.0651	Infect Rate:	%							

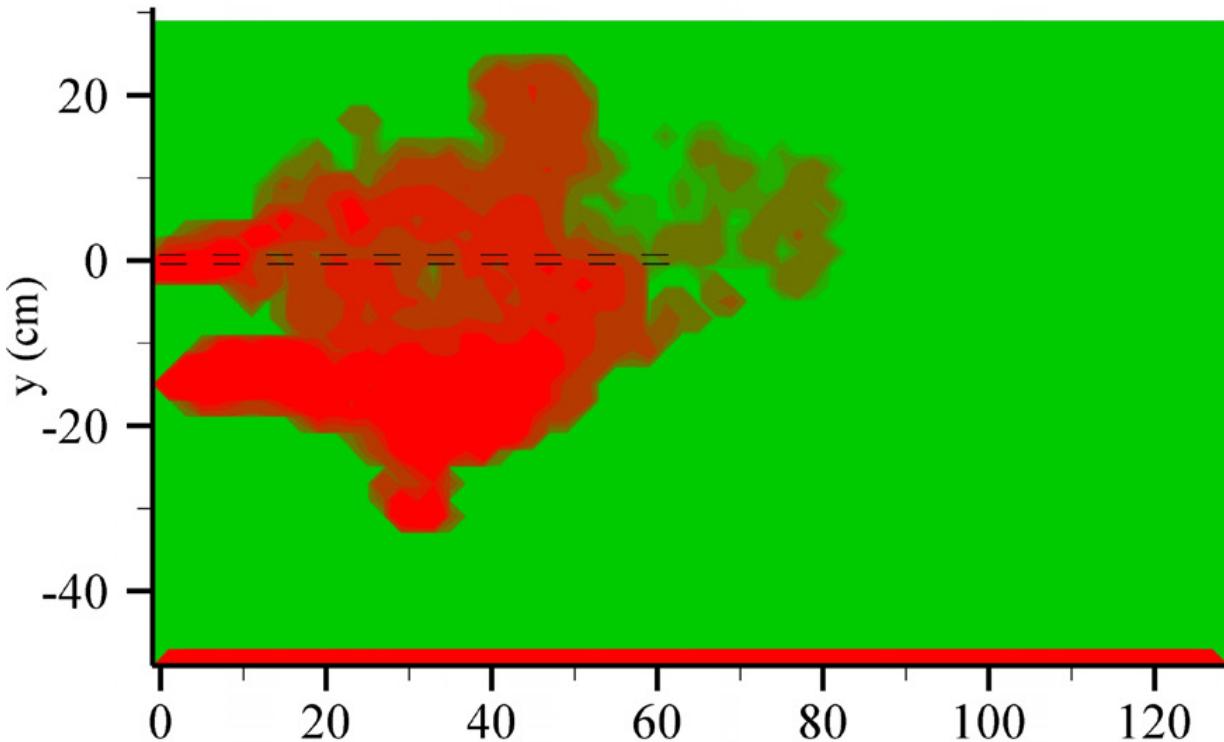
Potential Viral Load (based on particle size and concentration) from the Cough

Non-Evaporation



(a)

.0001 .001 .01 .1

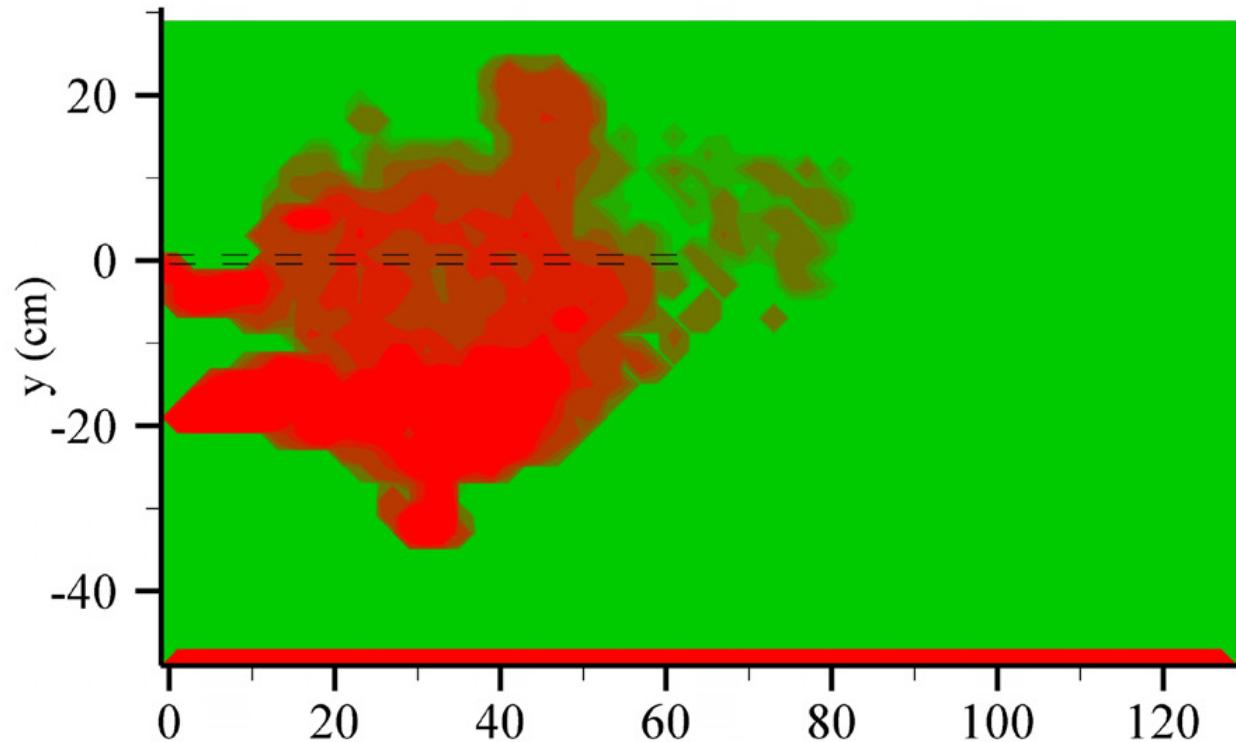


Non-Evaporation



(b)

.0001 .001 .01 .1



Room scale flow structure at 6 ACH

