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PRELIMINARY STUDY ON RELATIVE RISK OF SARS-COV 2 TRANSMISSION IN TERRACES

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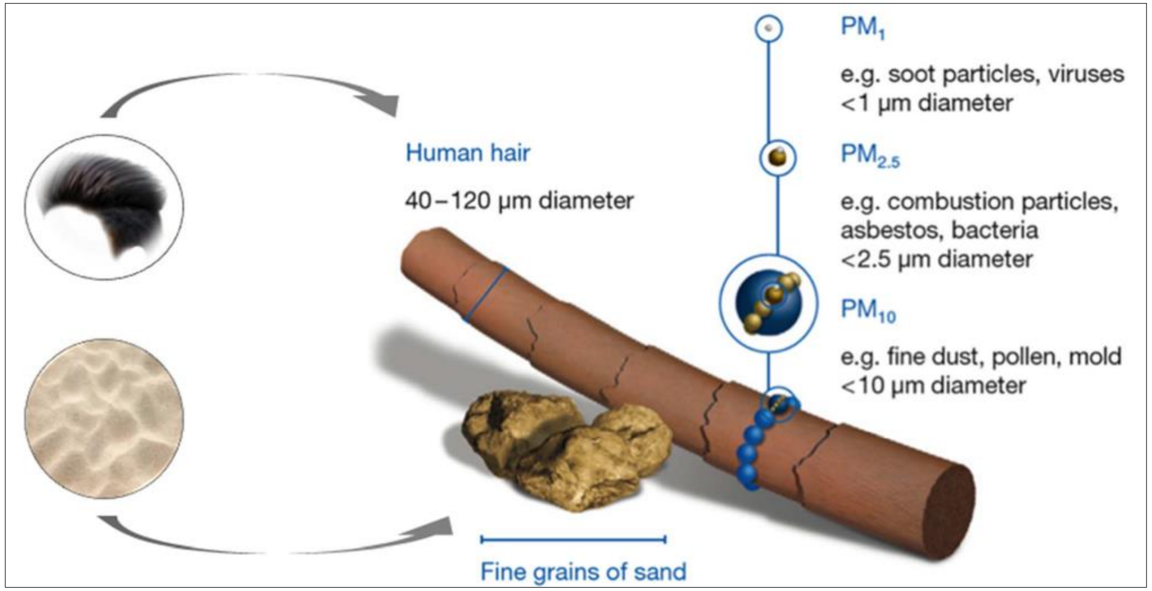
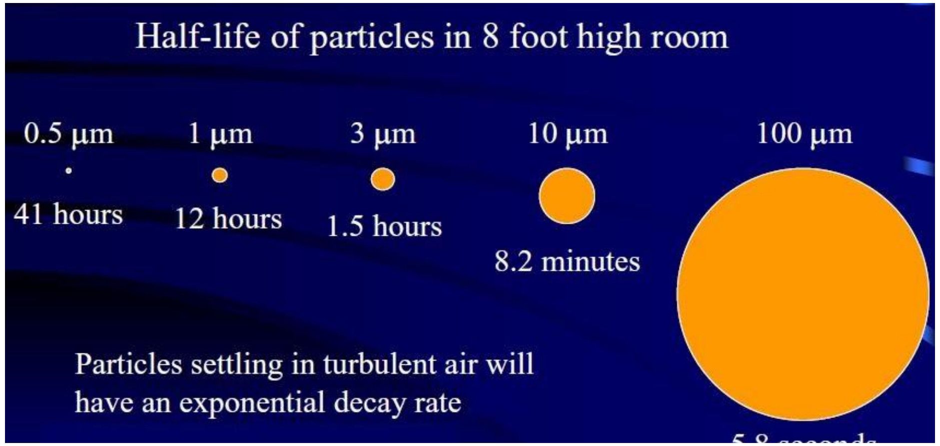
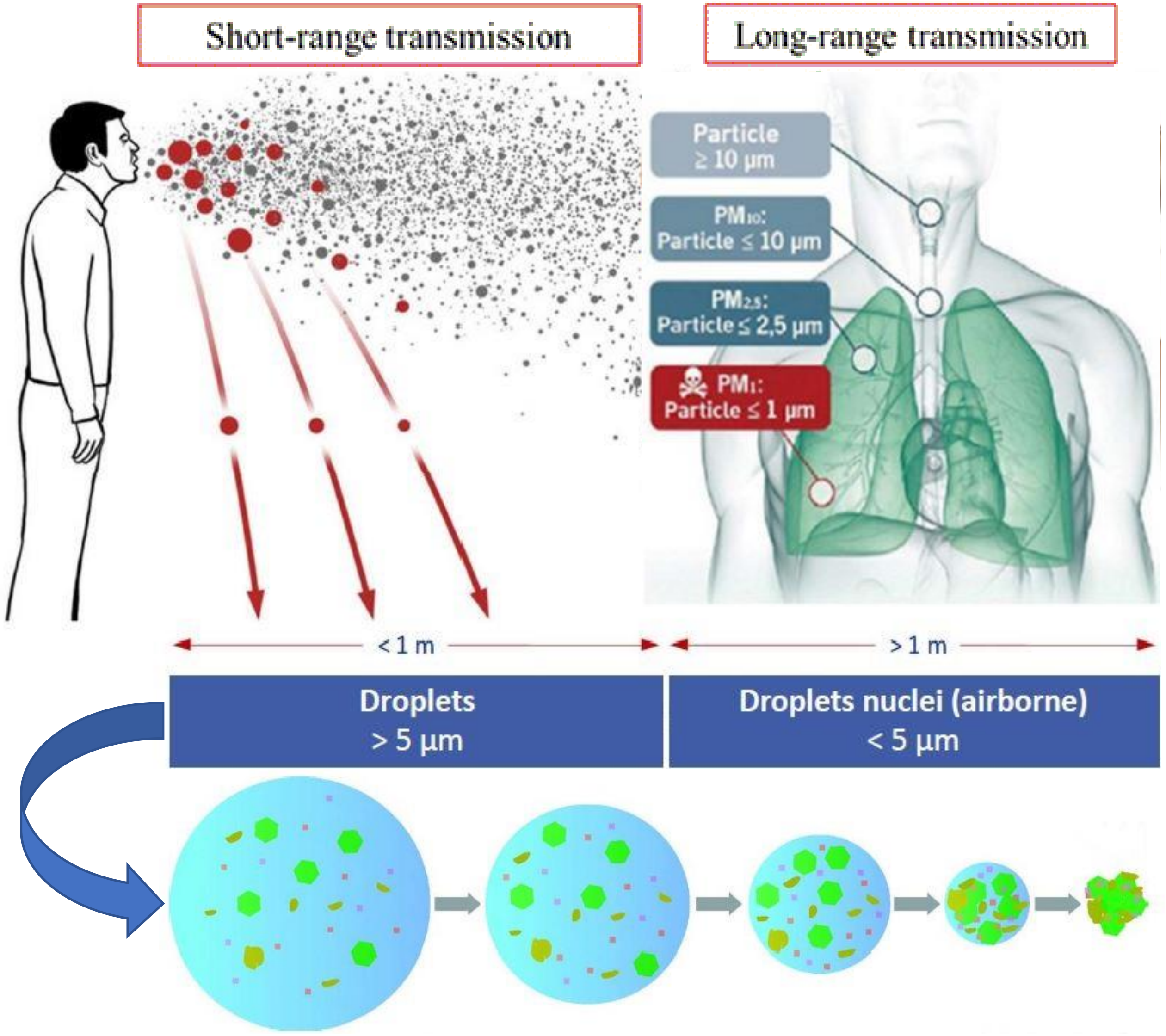
Introduction

AEROSOLS





BIOAEROSOLS GENERATION

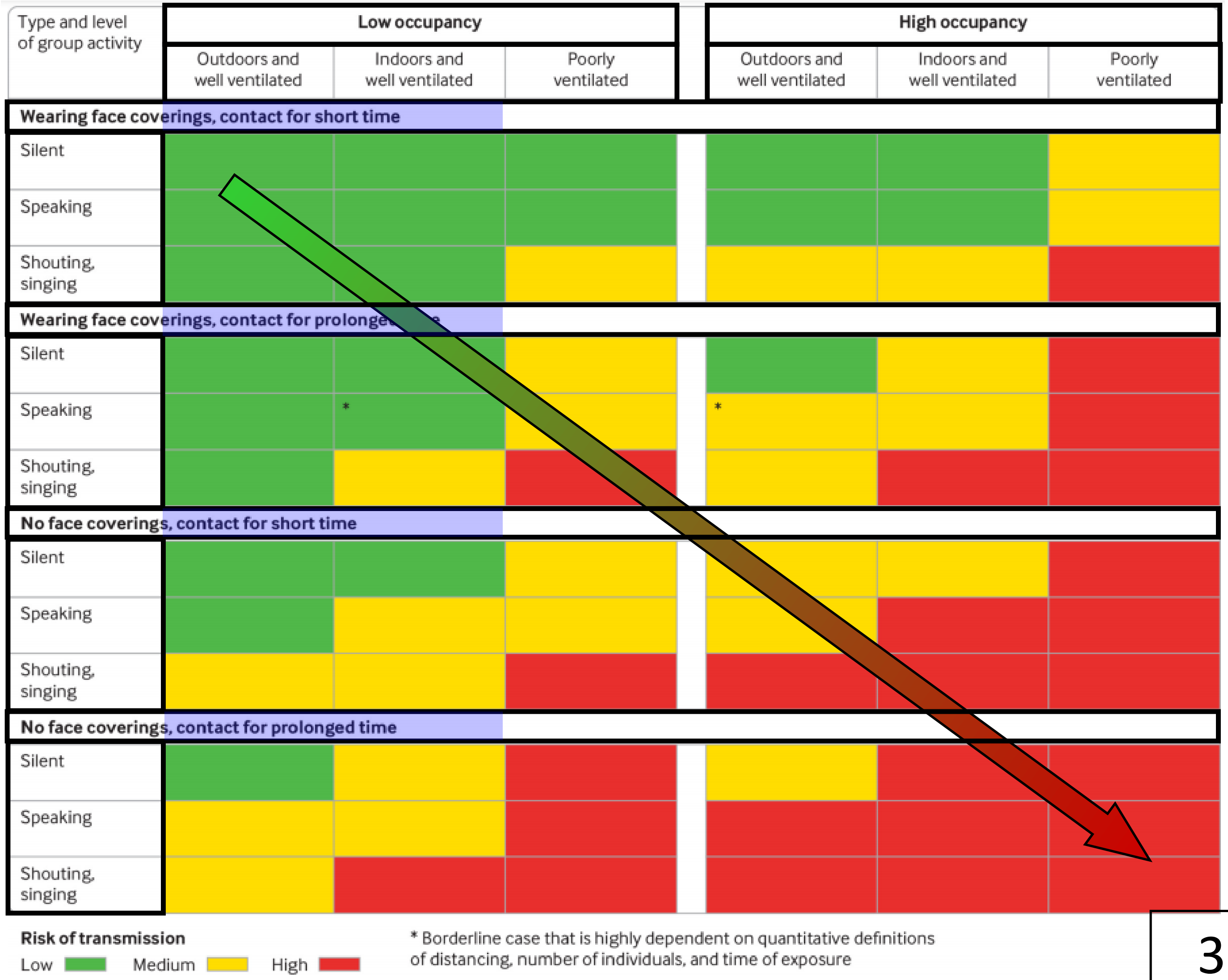


Bioaerosols play an essential role in the transmission of respiratory diseases

Time spent in a restaurant by age in EU

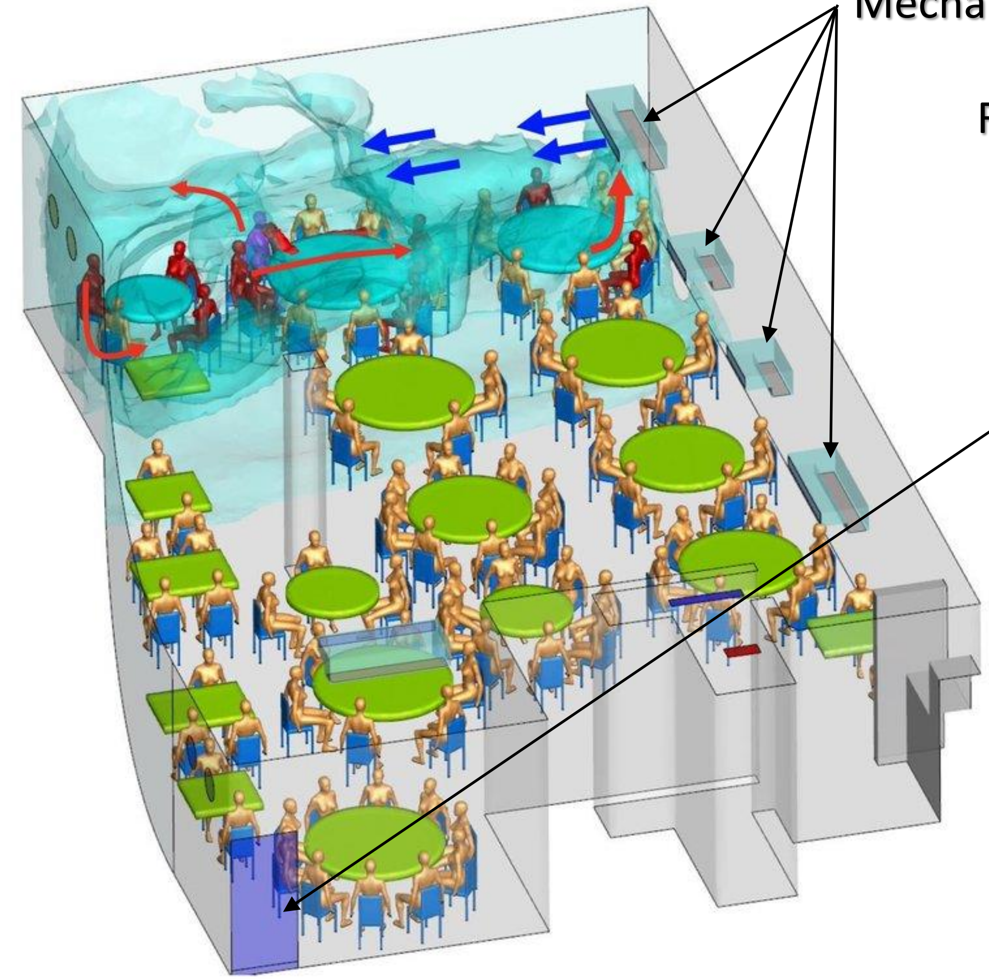
- Degree of occupancy
- Venting
- Crowding levels
- Face covering
- Occupation time

RISK OF SARS-CoV-2 TRANSMISSION IN DIFFERENT SETTINGS



*Eurostad (2004)
**Twitter Pablo Fuente (2020)
***Jones at al., 2020

CFD SIMULATIONS OF REAL INDOOR/SEMI-INDOOR ENVIROMENTS

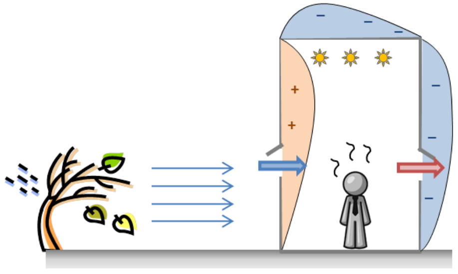


Mechanical Ventilation
↓
Fixed B. C. ✓

Natural Ventilation
↓
~~Fixed B. C.~~
↓
Meteorological B. C.

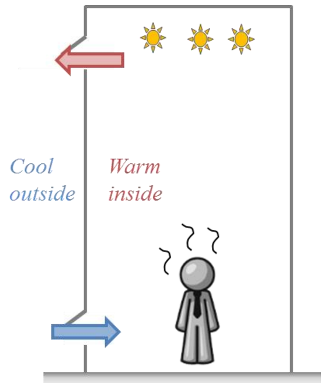
Driving forces of Natural Ventilation:

- Wind pressure



$$\Delta P_{hor} = \frac{1}{2}\rho v^2 (C_+ - C_-)$$

- Stack pressure (buoyancy)



$$\Delta P_{ver} = \rho g \beta z (T_+ - C_-)$$

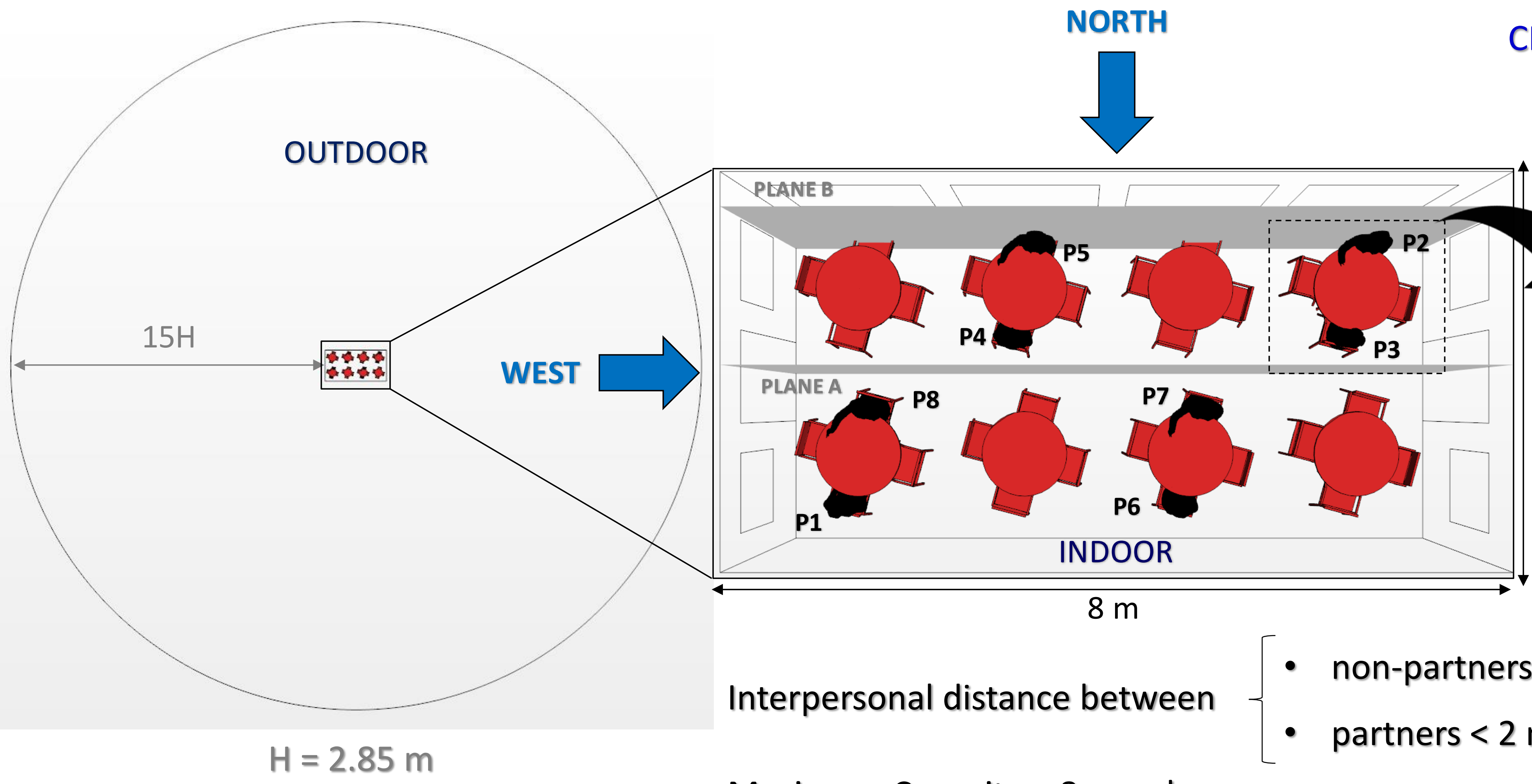
*Li et al., 2020
**http://coolvent.mit.edu/intro-to-natural-ventilation/basics-of-natural-ventilation

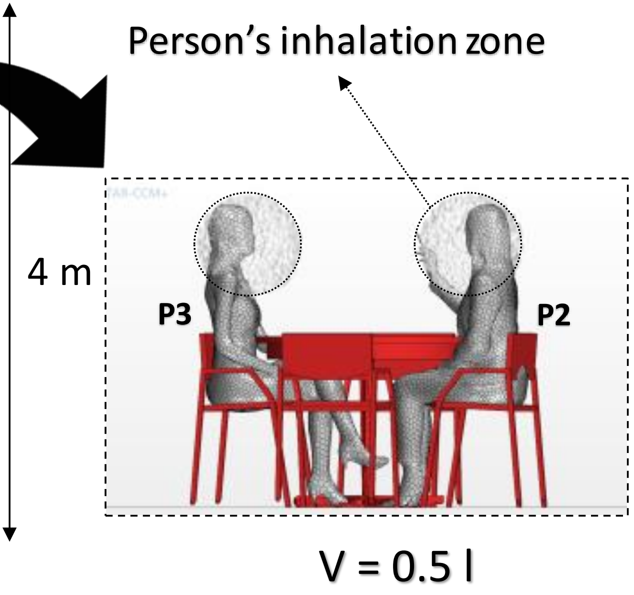
The objective of this work is to analyze the impact of natural ventilation on the relative risk of SARS-COV 2 transmission, using indoor CO_2 concentrations as a proxy, in a set of virtual indoor/semi-indoor scenarios representing different terrace configurations as function of the outdoor meteorological conditions using a Computational Fluid Dynamic (CFD) methodology.

Methodology

CFD Model → Geometry

CFD tool: STAR-CCM+9.04.011®



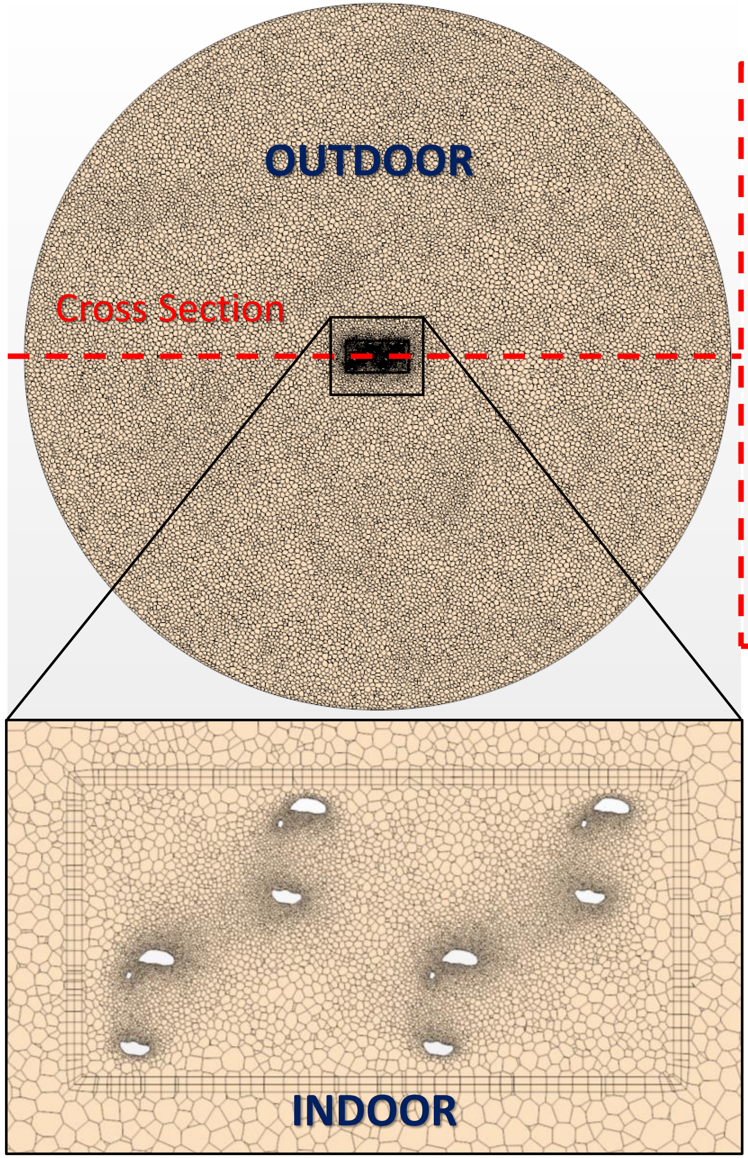


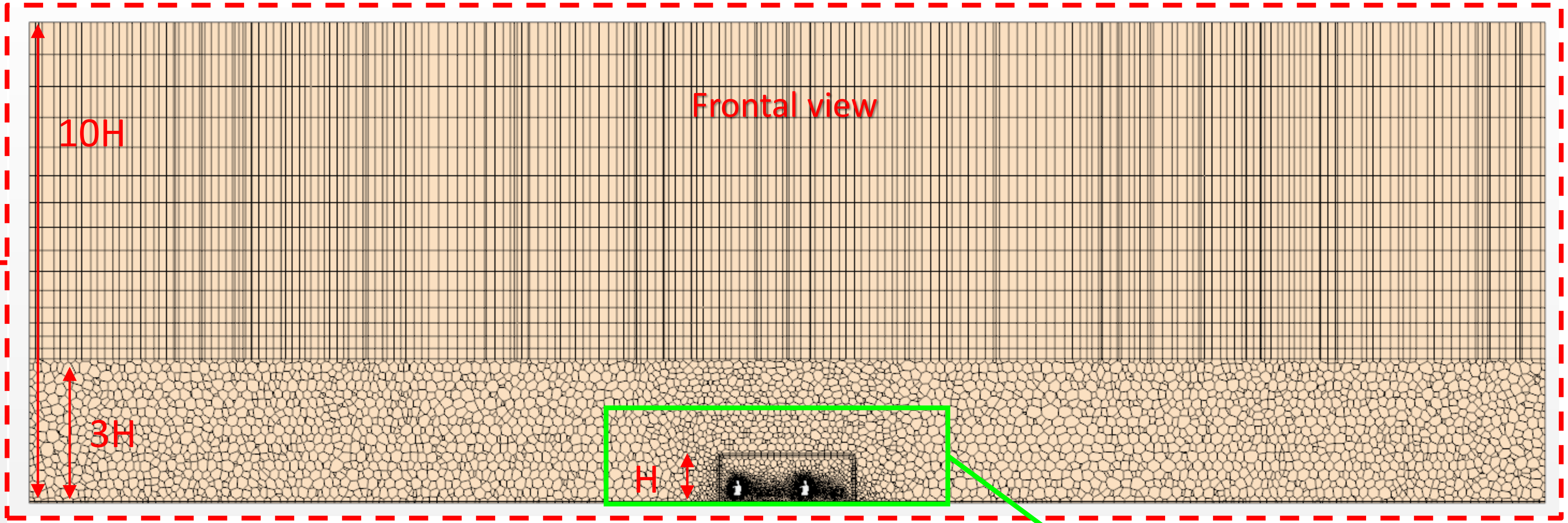
Interpersonal distance between
- non-partners > 2 m
- partners < 2 m

Maximum Capacity = 8 people

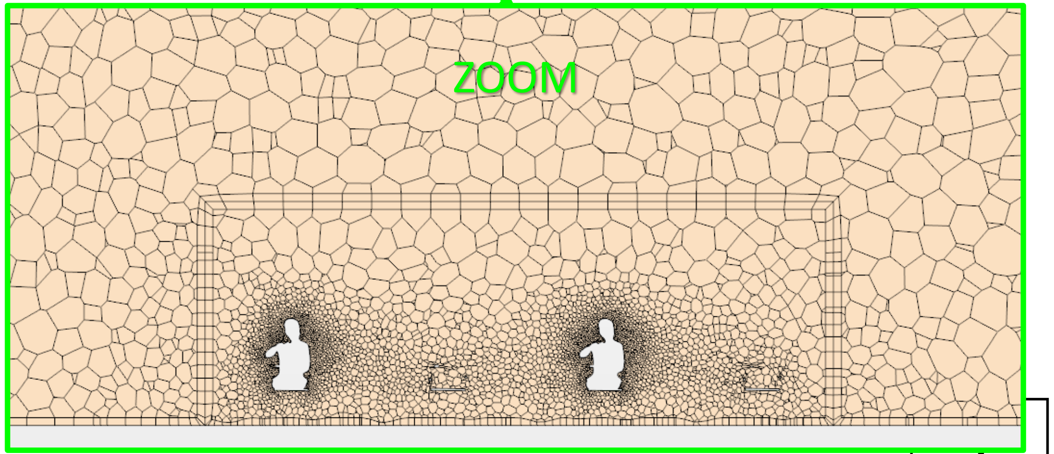
*Ordenanza de Terrazas y Quioscos de Hostelería y Restauración. Boletín Oficial del Ayuntamiento de Madrid, núm. 6977 de 6 de agosto de 2013. Ayuntamiento de Madrid.
**https://www.3dcadbrowser.com/
***https://grabcad.com
****Franke et al., 2000

CFD tool: STAR-CCM+9.04.011®





- Typical cell sizes
  - ΔV = 1 m
  - ΔS = 0.5 m
- 1 Prism Layer = 0.1 m
- Refinements around PEOPLE
- Total number of cells: $1.3 \cdot 10^6$



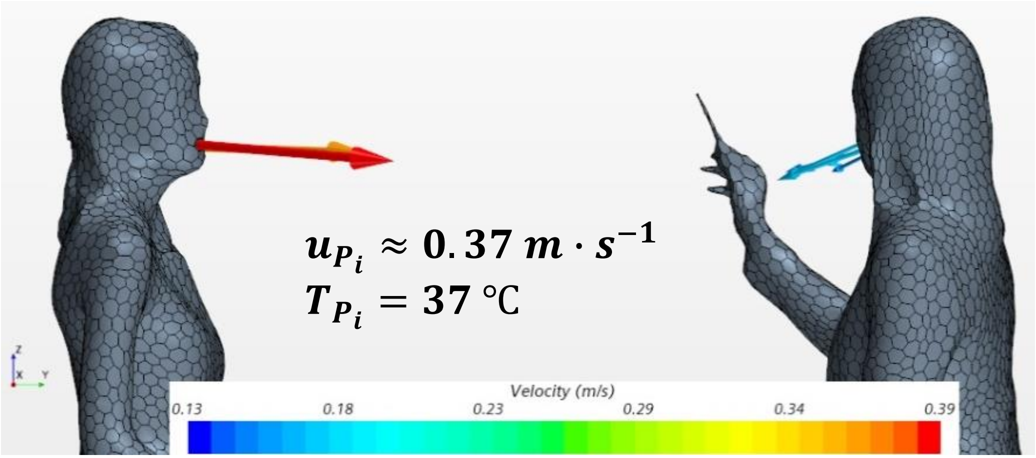
*Franke et al., 2007

Methodology

CFD Model →Physics

– CFD Model –

- ❑ Unsteady Simulations
- ❑ Segregated Flow and Energy
- ❑ *URANS* Model:
  - ▪ *Realizable K-ε* Two-Layer model
- ❑ AIR → Ideal Gas
- ❑ Exhaled CO_2 → P_i Passive Scalars (5 % Vol.)



– Boundary Conditions –

- ❑ Free Stream:

$$\left.\begin{aligned} u(z) &= \frac{u_*}{\kappa} ln\left(\frac{z+z_0}{z_0}\right) \\ k &= u_*^2 / \sqrt{C_\mu} \\ \varepsilon &= u_*^3 / \kappa\,(z+z_0) \\ T(z) &= Neutral \end{aligned}\right\} \rightarrow \begin{aligned} u_{10} &= 1.6\ m \cdot s^{-1} \\ T &= 7\ °C \end{aligned}$$

- ❑ Ground → Roughness
- ❑ Top → Symmetry
- ❑ Surfaces → Adiabatic except People ($T_{Sur} = 23$ °C)
- ❑ Radiative effects → Neglected

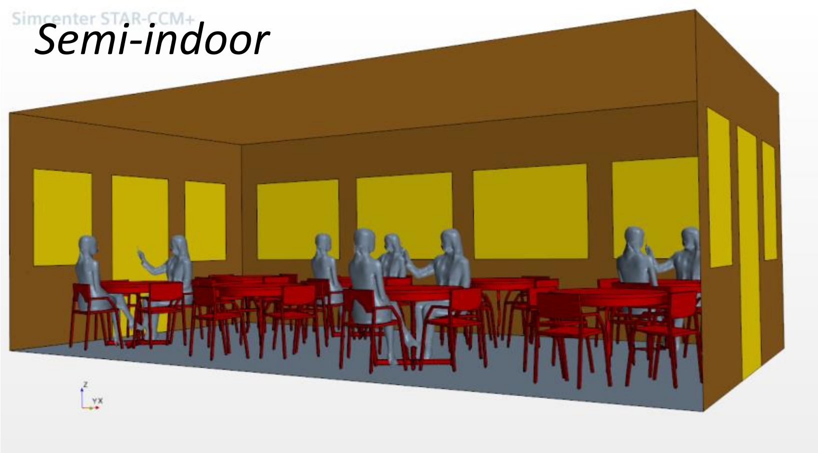
Average CLO = 0.7
Average MET = 1.5
Average Surface = 1.55 m^2
75% Thermal Losses

Two Wind Directions → West and North

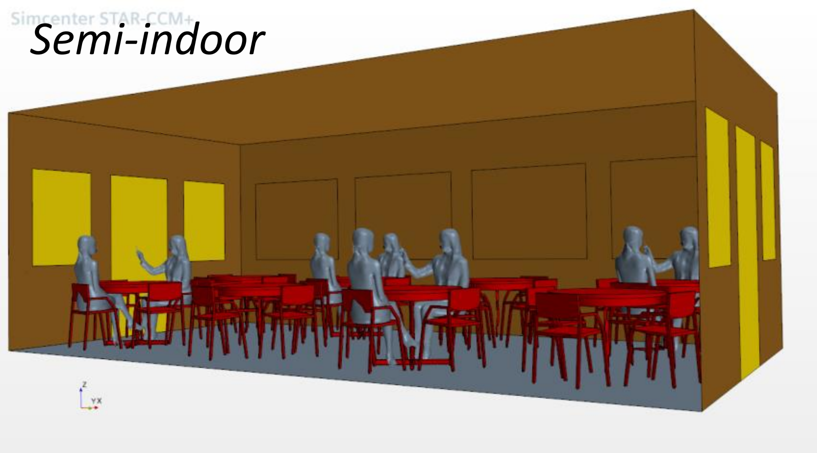
Methodology

Virtual Scenarios

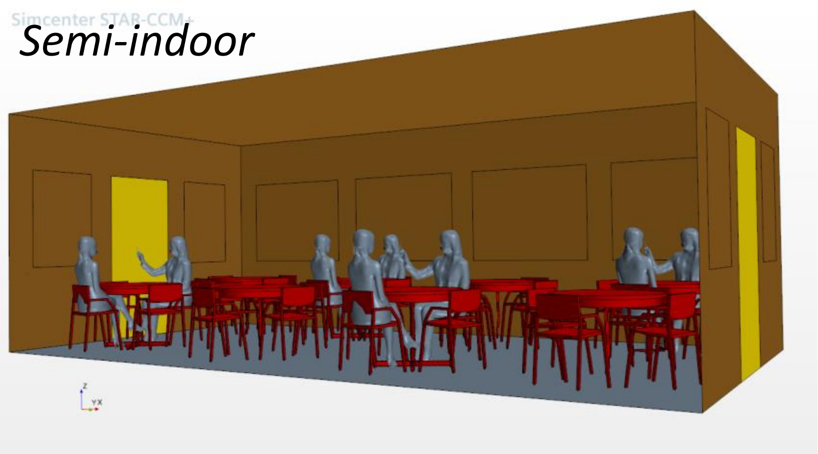
Scenario 0



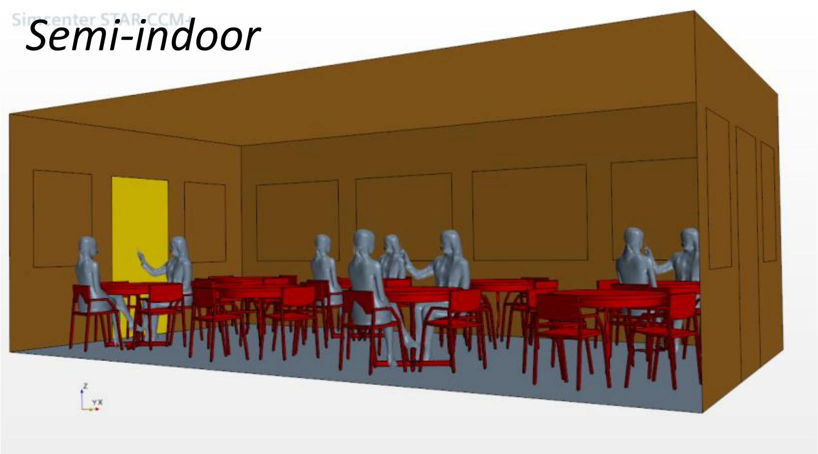
Scenario 1



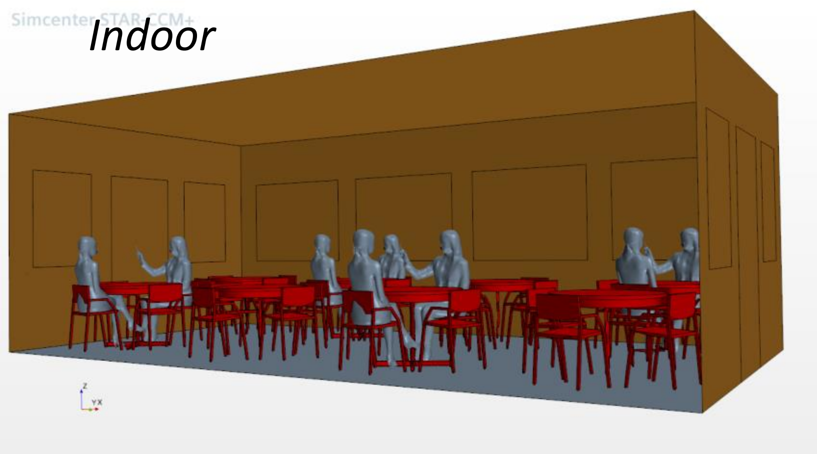
Scenario 2



Scenario 3



Scenario 4

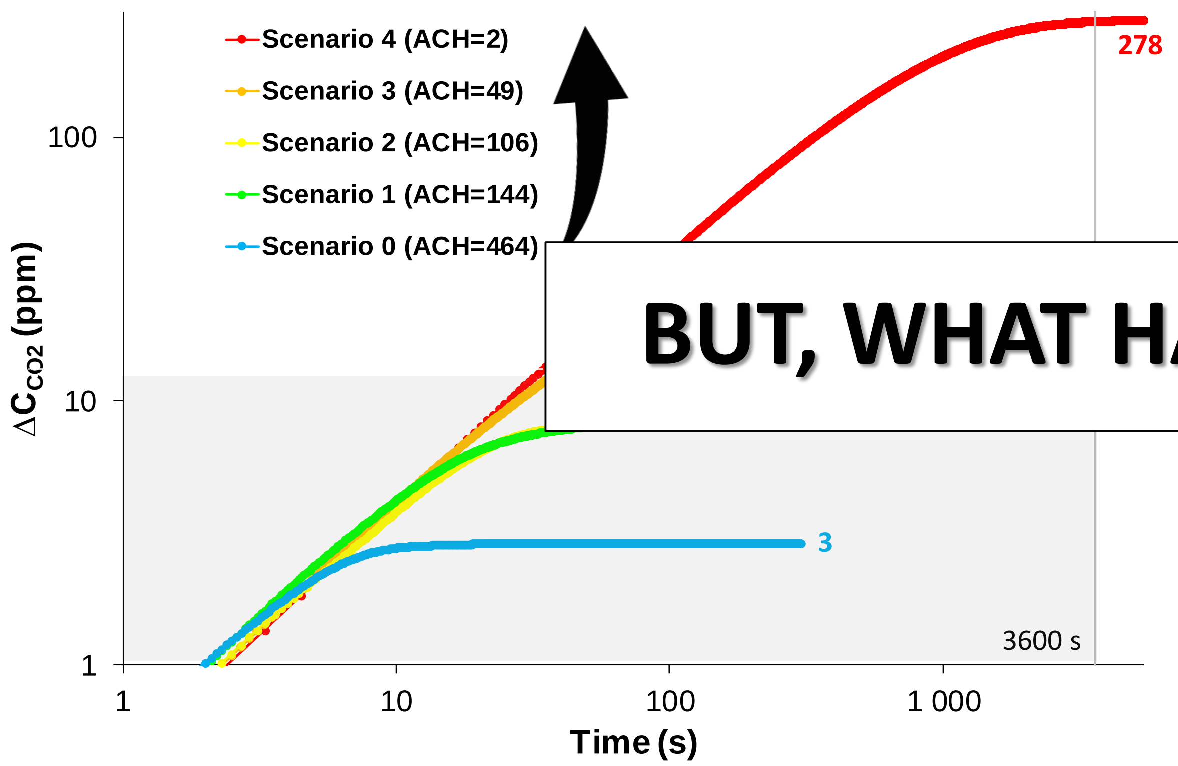


Scenario 5

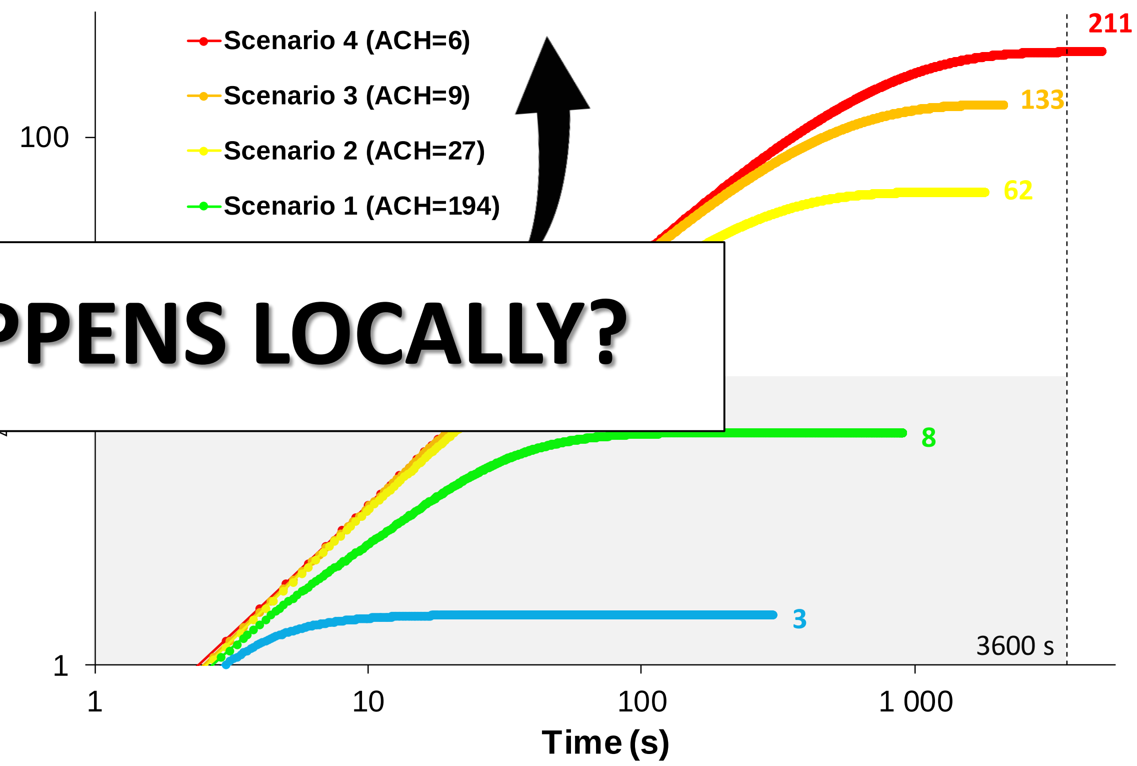
Wind direction effect on the indoor volume average of ΔC_{CO_2}

Time evolution of indoor volume average of ΔC_{CO_2} for different values of *Air Change per Hour* (ACH)

West wind direction



North wind direction



BUT, WHAT HAPPENS LOCALLY?

As ACH decreases
- unsteady period increases
- In general, indoor volume average of ΔC_{CO_2} increases

On cases with ACH ≥ 144

⇩

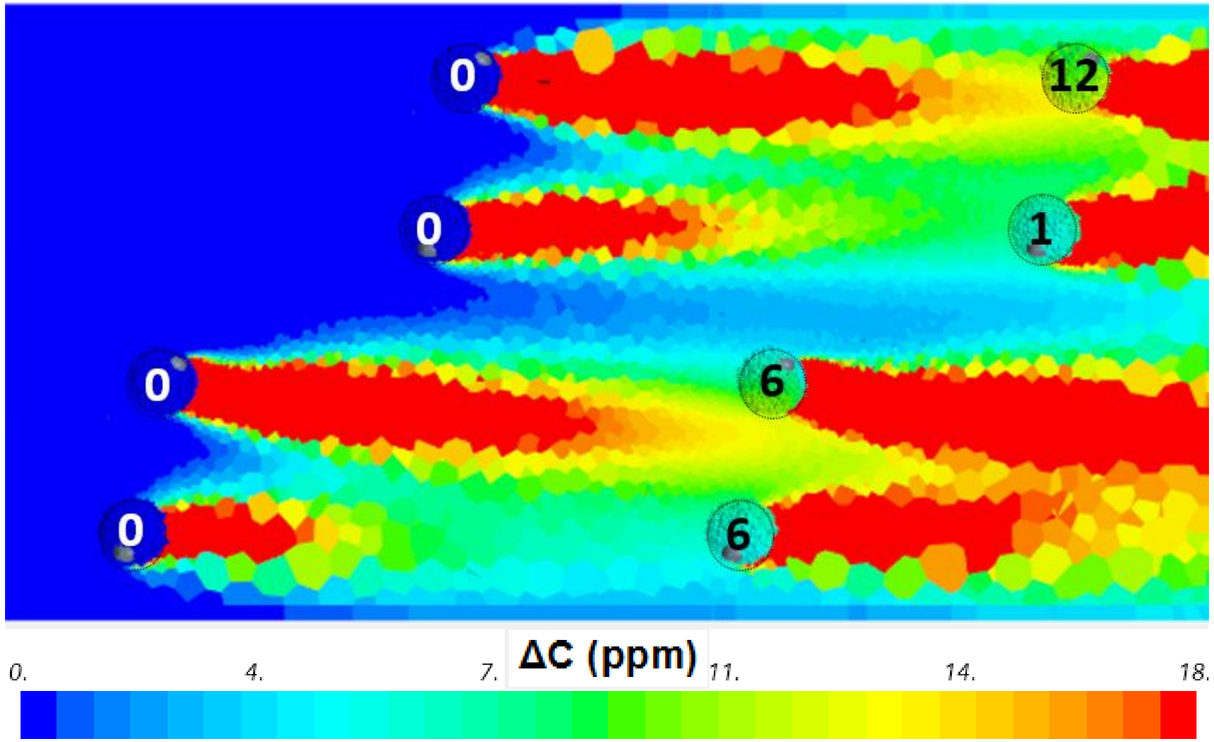
Wind direction has **no impact**

Results

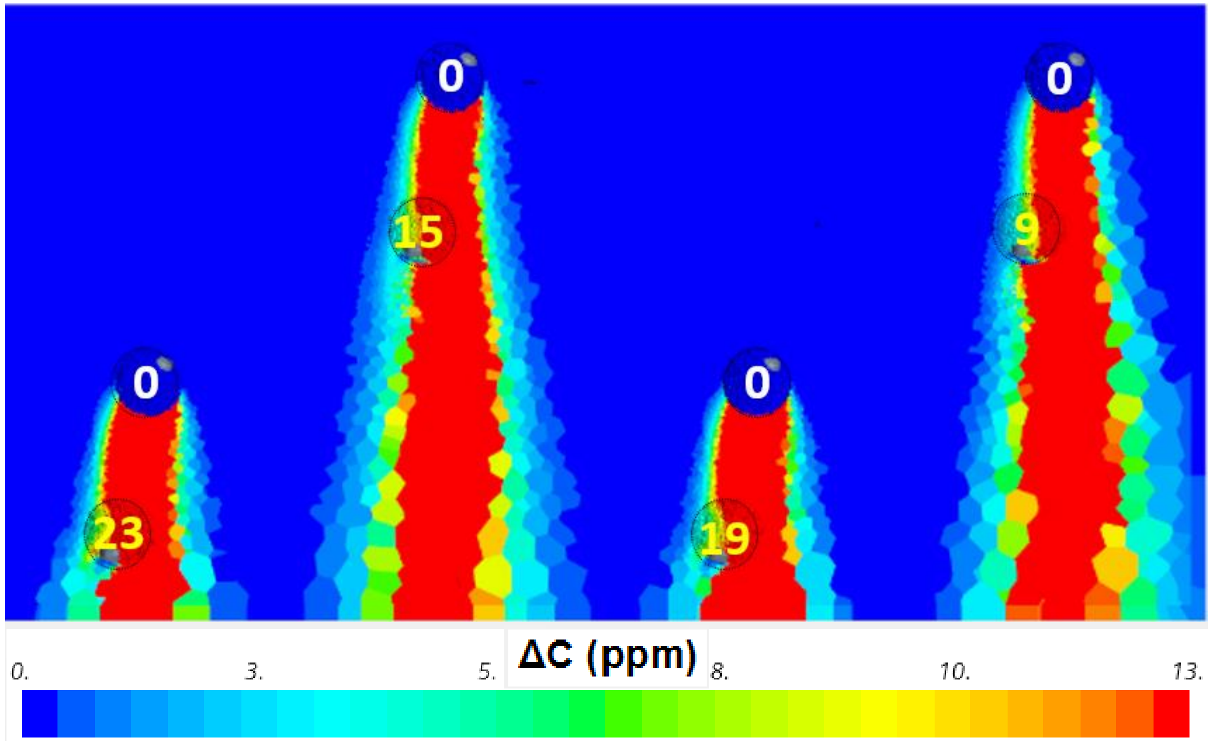
Wind direction effect on the ΔC_{CO_2} high resolution map at 1.2 m height

ΔC_{CO_2} high resolution map at 1.2 m height and volume average of ΔC_{CO_2} incoming to each person from the others

West wind direction



North wind direction

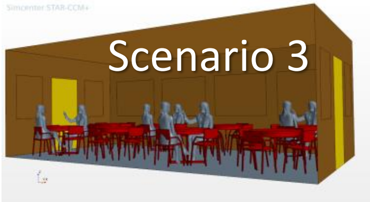


Under certain meteorological conditions, the non-partners influence could be greater than the partners

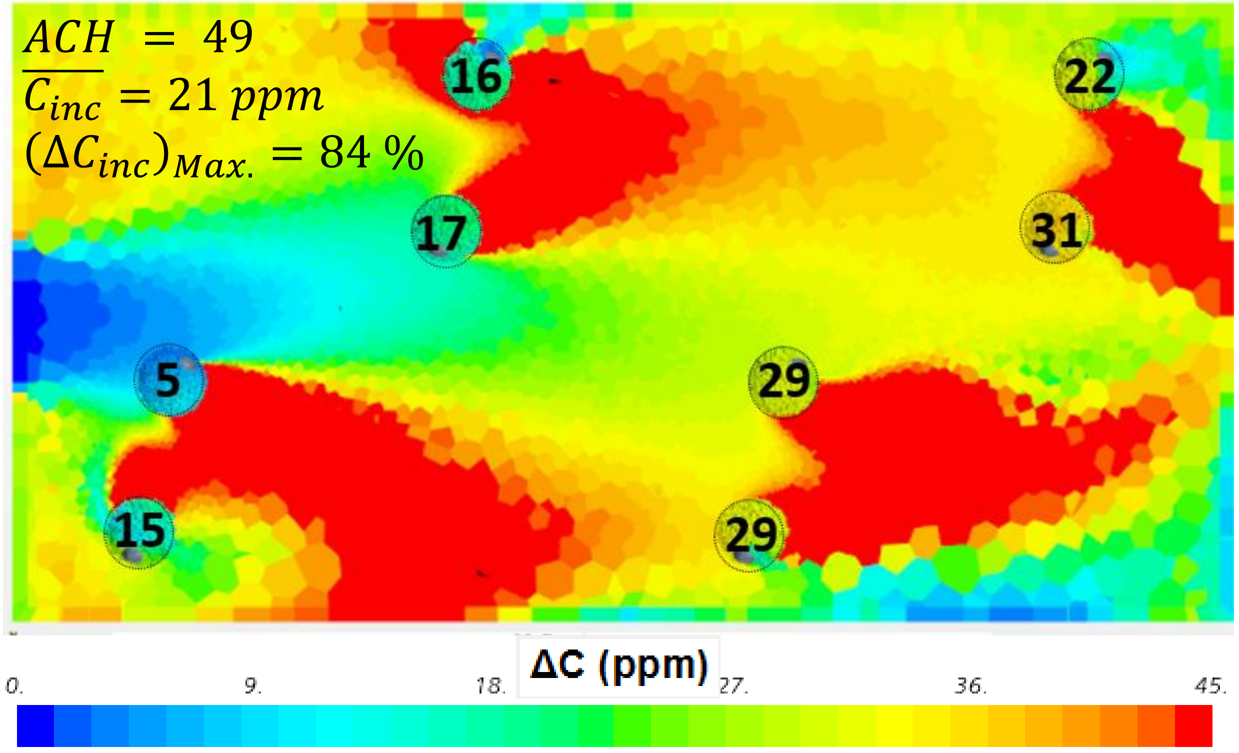
Red color indicates values greater or equal than upper values of respective scales.
Upper values correspond with the indoor surface average of ΔC_{CO_2} at 1.2 m height of each case during the steady state.

Wind direction effect on the ΔC_{CO_2} high resolution map at 1.2 m height

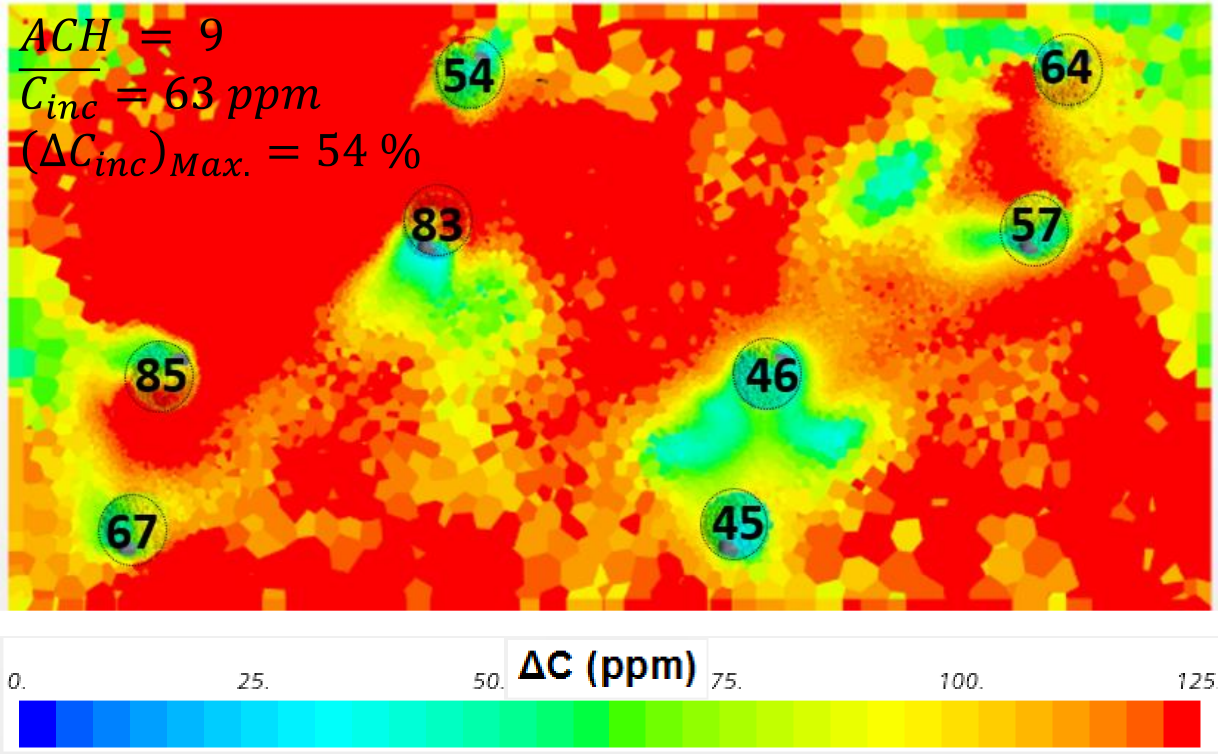
ΔC_{CO_2} high resolution map at 1.2 m height and volume average of ΔC_{CO_2} incoming to each person from the others



West wind direction



North wind direction

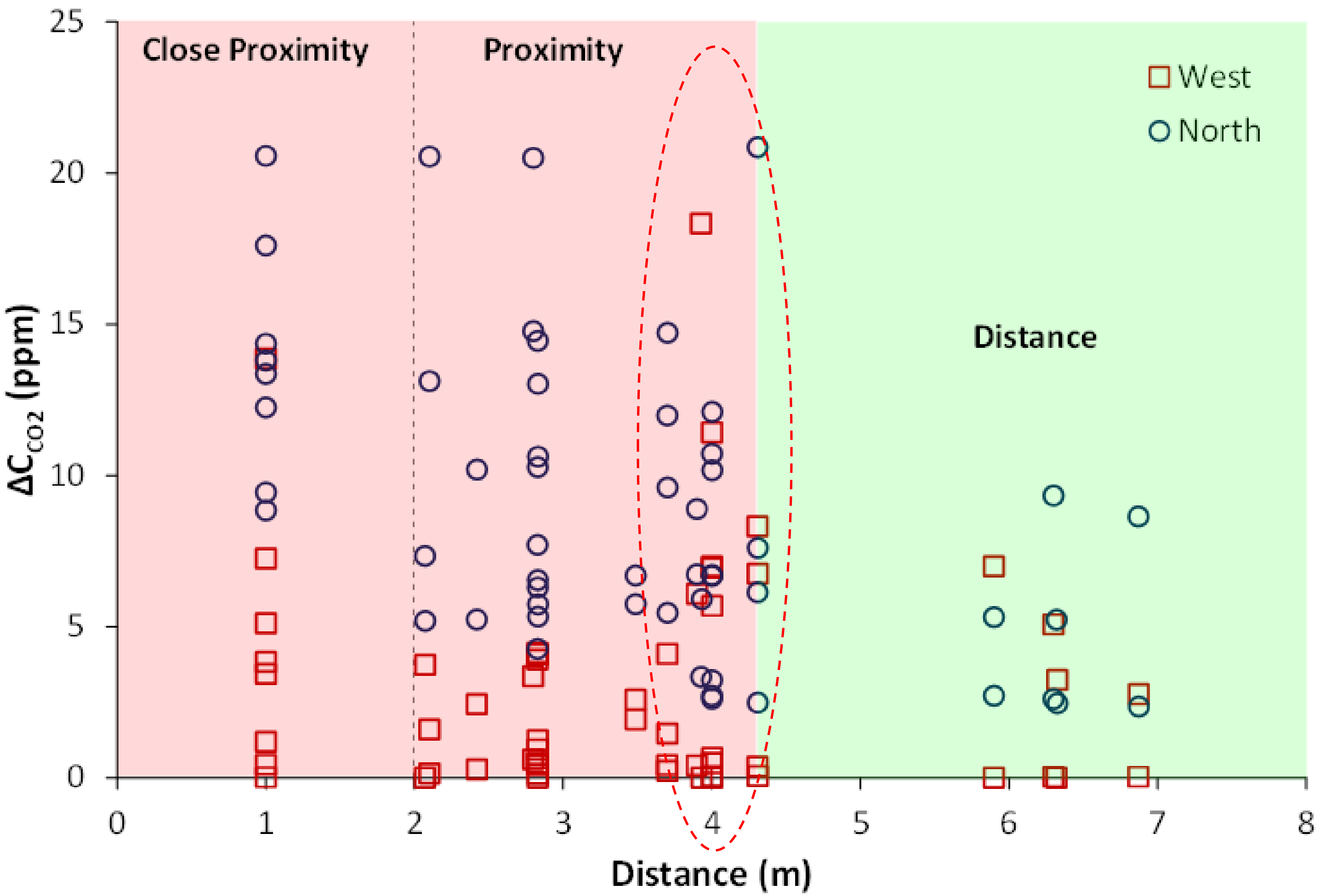


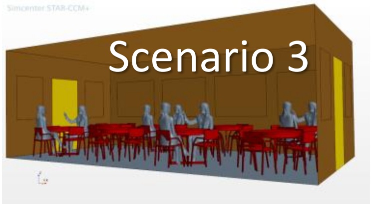
Ventilation is important, but not only

Red color indicates values greater or equal than upper values of respective scales.
Upper values correspond with the indoor surface average of ΔC_{CO_2} at 1.2 m height of each case during the steady state.

Wind direction effect on the volume average of ΔC_{CO_2} incoming to P_i from the others

Volume average of ΔC_{CO_2} incoming to P_i from the others during the steady state





In shared settings it is recommended:

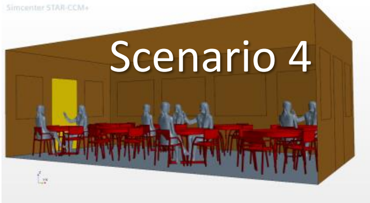
to increase the ventilation in order to prevent the short-range transmission, which is higher than the long-range transmission

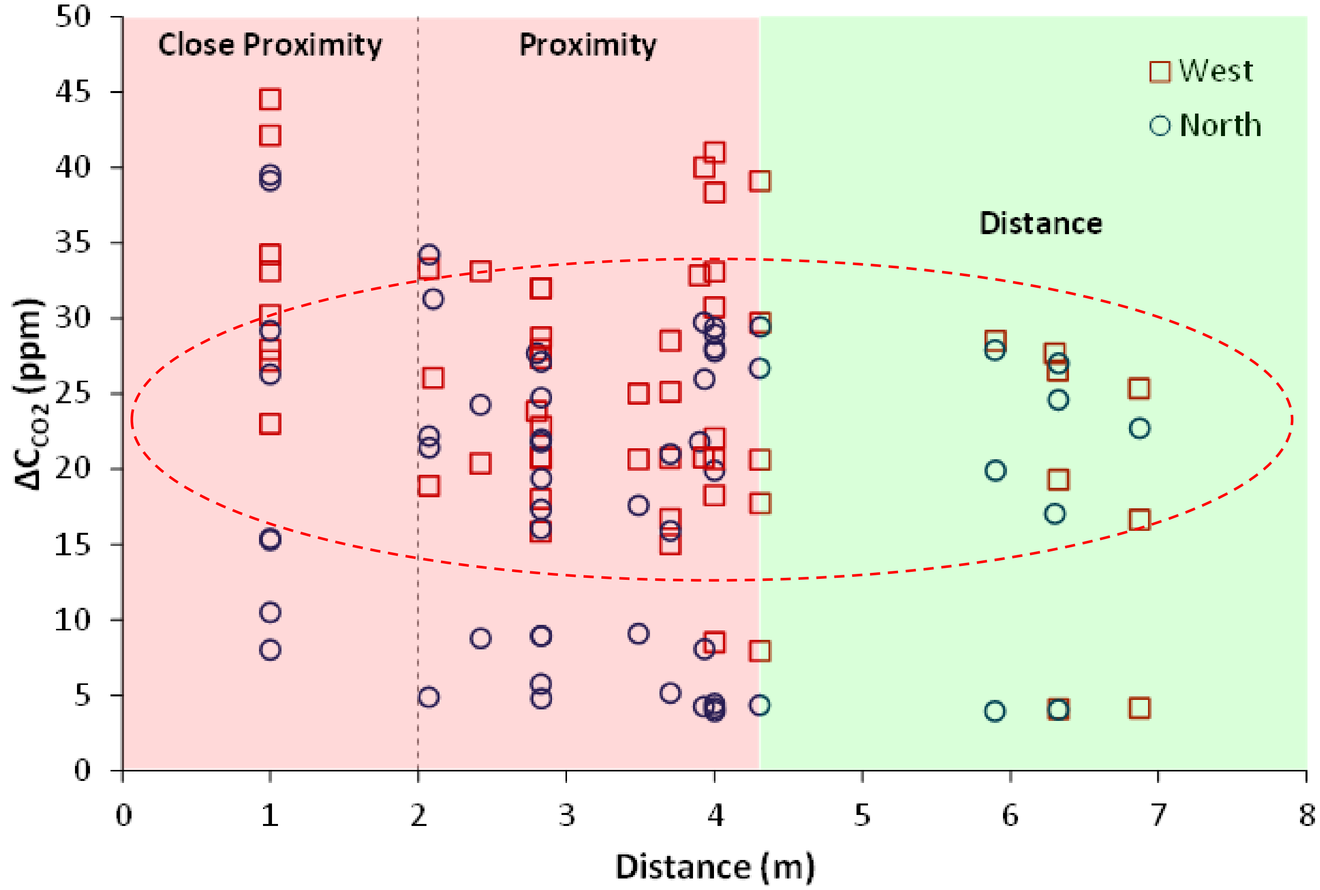
to minimize the impact of potential flow patterns created by the increasing ventilation

Indoor flow patterns between infectors and susceptibles determine the individual incoming concentrations

Wind direction effect on the volume average of ΔC_{CO_2} incoming to P_i from the others

Volume average of ΔC_{CO_2} incoming to P_i from the others during the steady state



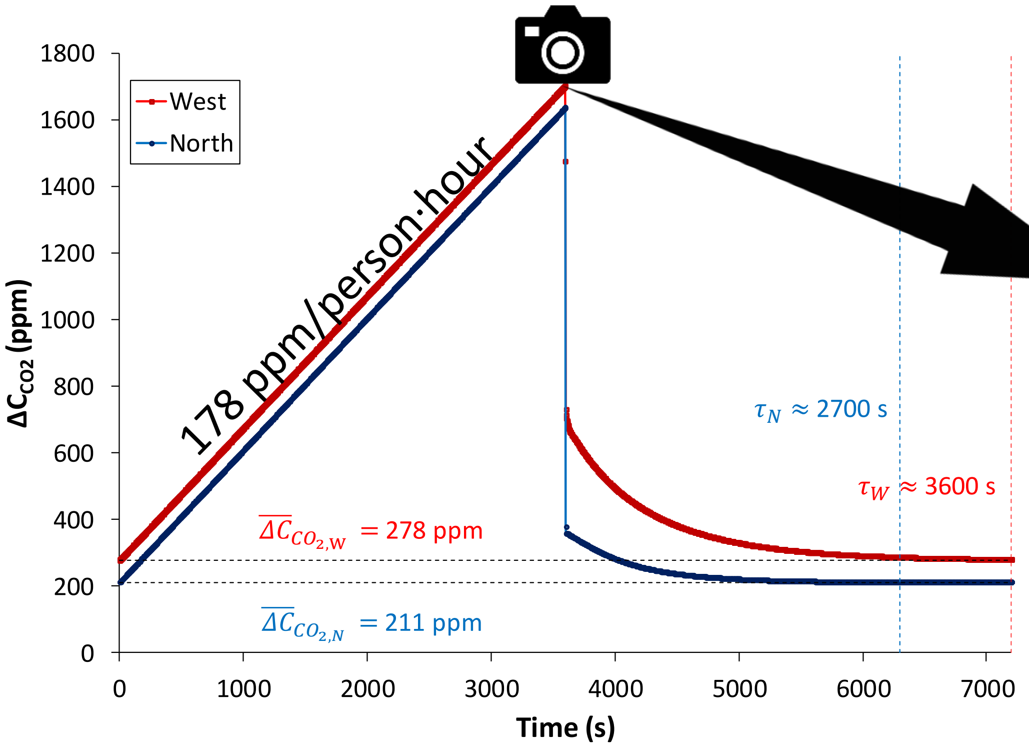


In poorly ventilated scenarios, measures based on the social distance between people have a negligible impact to reducing the cross-infection risk

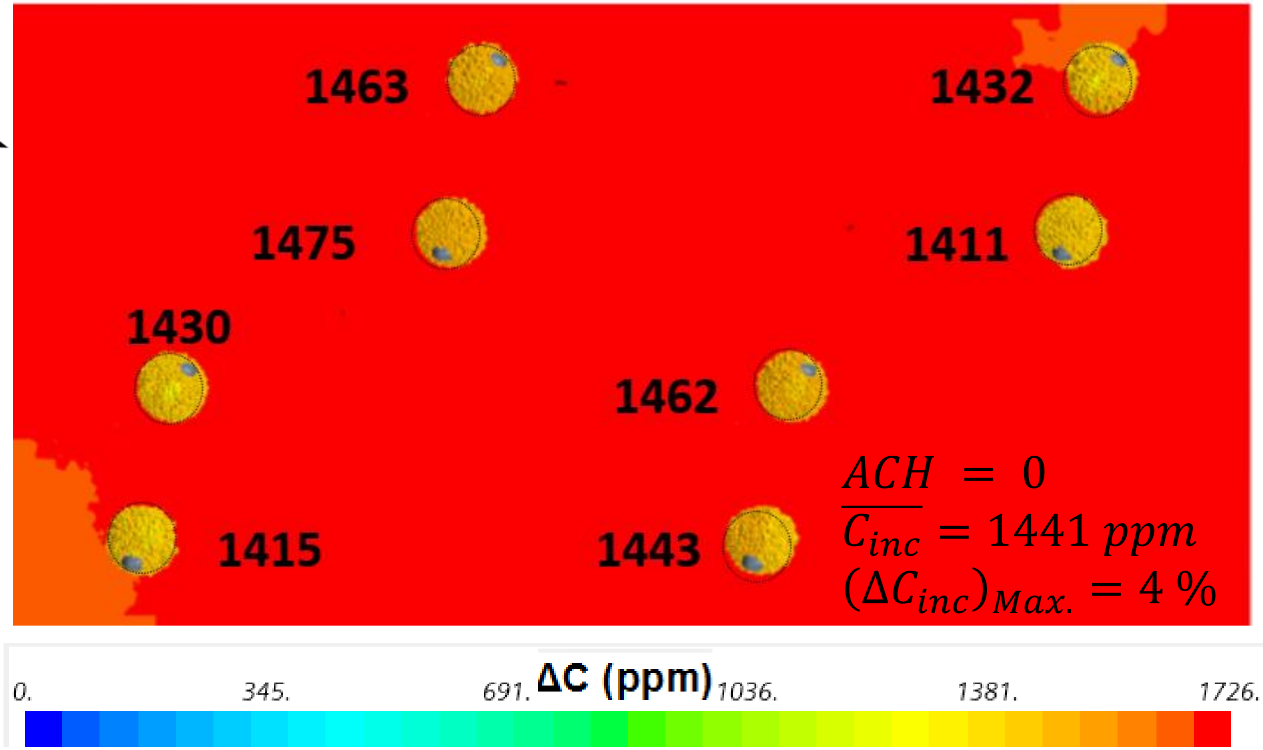
Results

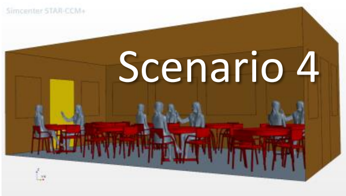
Wind direction effect on the ΔC_{CO_2} high resolution map at 1.2 m height

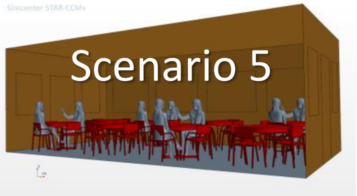
Time evolutions of indoor volume average of ΔC_{CO_2}

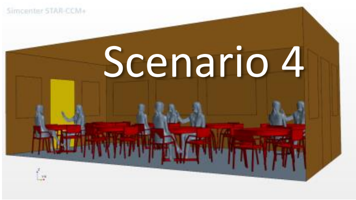


ΔC_{CO_2} high resolution map at 1.2 m height and volume average of ΔC_{CO_2} incoming to each person from the others in 1 hour









In Scenario 5:

- in 1 hour, the average incoming concentration is between 7 and 11 times higher than in Scenario 4
- the assumption of a completely mixed flow inside the terrace would be appropriate

Conclusions

- In outdoor terraces, short-range transmission prevails. But under certain meteorological conditions, the non-partners influence could be greater than the partners
- In semi-indoor terraces:
  - In general, the higher the ventilation, the lower the average risk of SARS-COV 2 transmission. For example, in Scenario 4 (a poorly ventilated scenario), it is between 15 and 25 times higher than in Scenario 0 (outdoor scenario)
  - But, the individual risks of SARS-COV 2 transmission depend on the flow patterns between infectors and susceptibles
- In indoor terraces:
  - Short-range transmission is practically equal to long-range transmission
  - Box models are adequate for individual risk assessments

These CFD results can be useful:

- To better understanding the transport phenomena of bio-aerosols
- To improve the safety in terraces by means of natural ventilation
- To advise on the design of indoor/semi-indoor environments

HARMO 20

THANK YOU

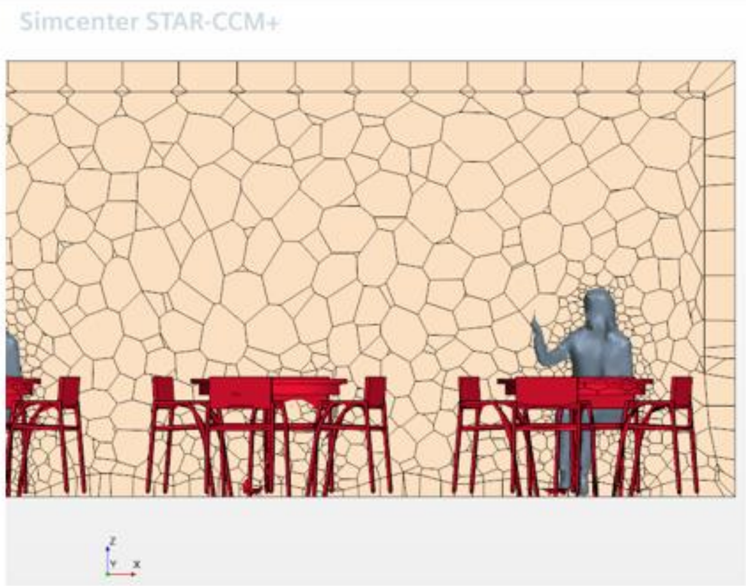
Additional Slides

Mesh test

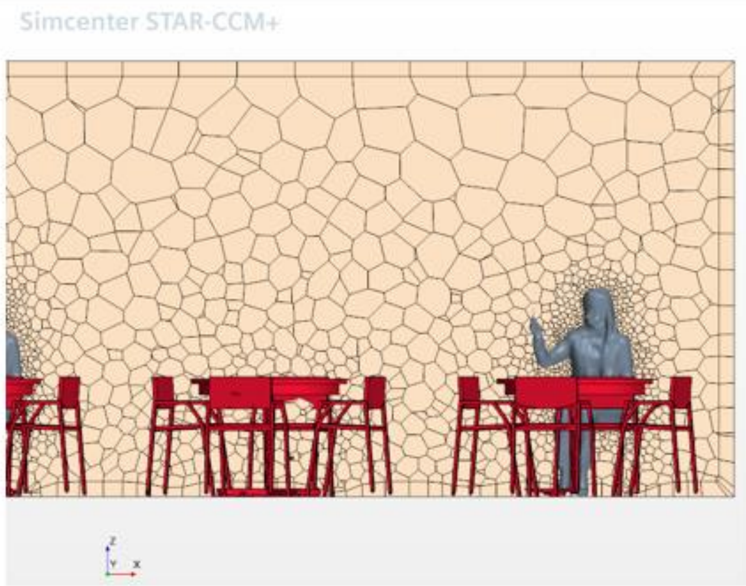
Meshing characteristics

Mesh		*Coarse*	*Medium*	*Fine*
Total number of cells		310301	1286223	6399519
ΔV (m)		2	1	0.5
ΔS (m)	Terrace enclosures and tables/chairs	1	0.5	0.25
	People	0.2	0.1	0.05
Refinement (m)	Terrace enclosures and tables/chairs	0.2	0.1	0.05
	People	0.04	0.02	0.01
Prism layer thickness (m)		0.2	0.1	0.05

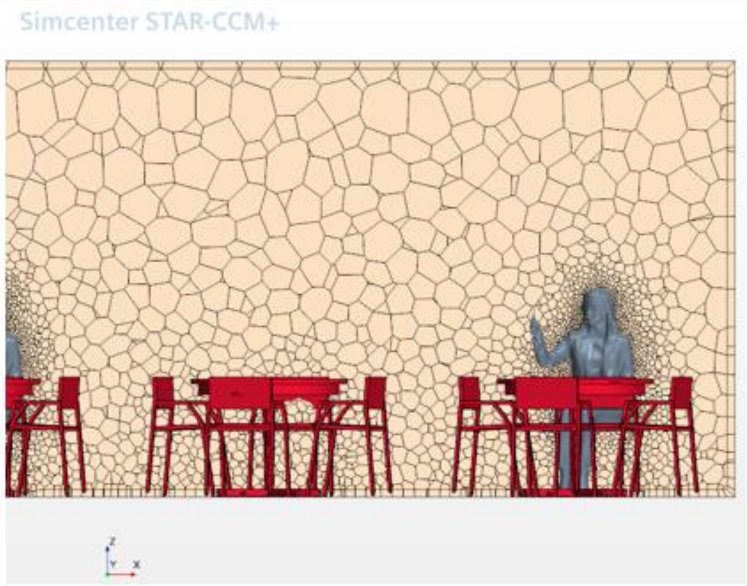
Coarse



Medium

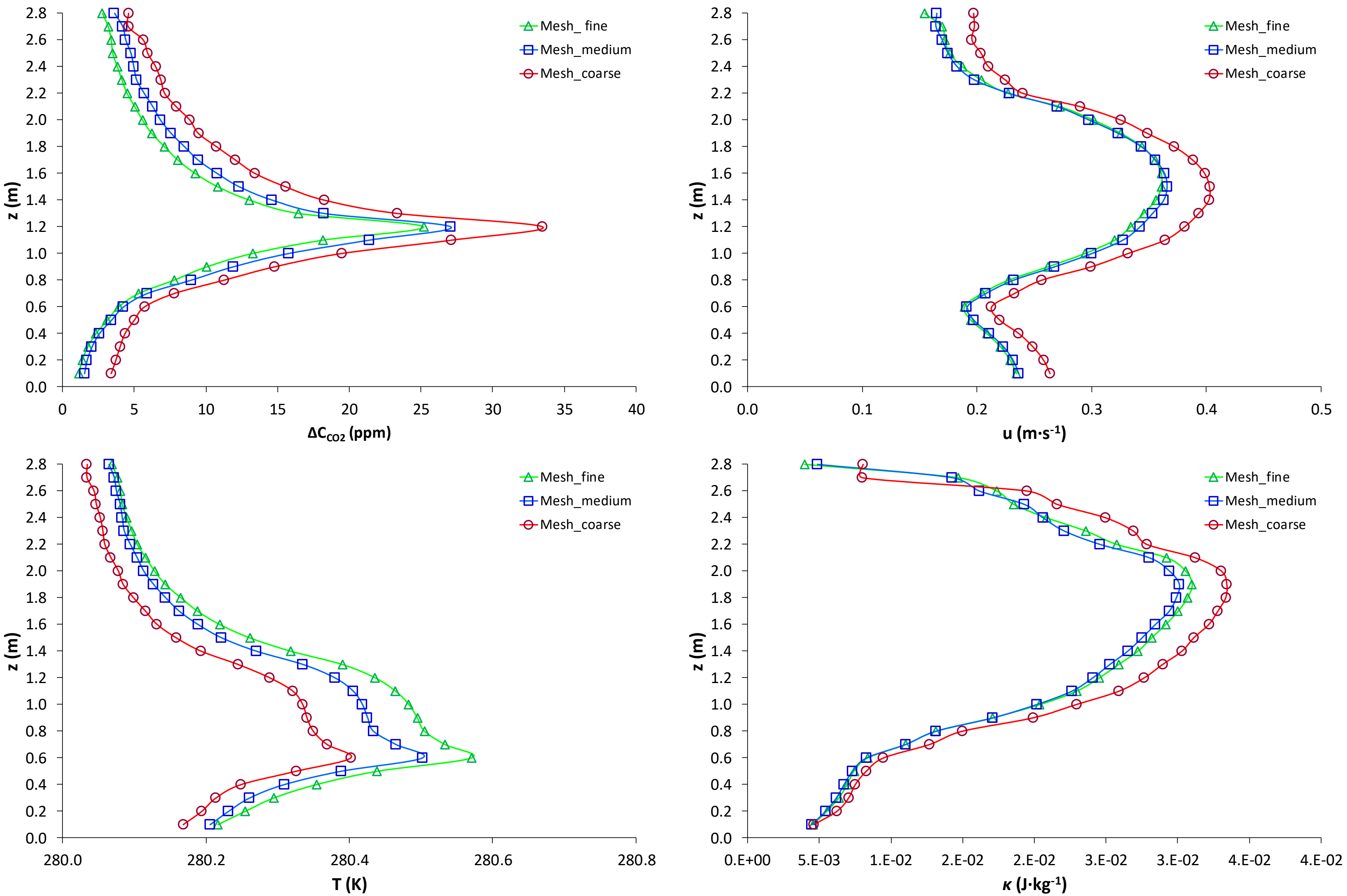


Fine



Mesh test

Indoor profiles for BCD1OD2OW1CW2CTCWC scenario and West wind direction during the steady state



Mesh test

Statistical parameters comparing *Mesh_fine* results with *Mesh_medium* and *Mesh_coarse* results

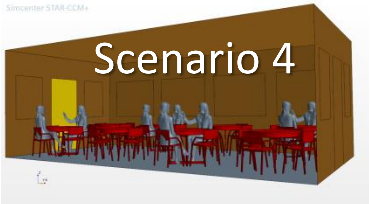
	Mesh_medium				*Mesh_coarse*			
	R	***NMSE***	***RMSE***	***FB***	***R***	***NMSE***	***RMSE***	***FB***
ΔC_{CO_2}	0.998	0.031	1.371	-0.154	0.997	0.216	4.082	-0.403
T	0.999	0.000	0.041	0.000	0.995	0.000	0.101	0.000
u	0.998	0.000	0.005	-0.007	0.994	0.014	0.032	-0.113
κ	0.999	0.001	0.001	0.023	0.984	0.019	0.003	-0.099

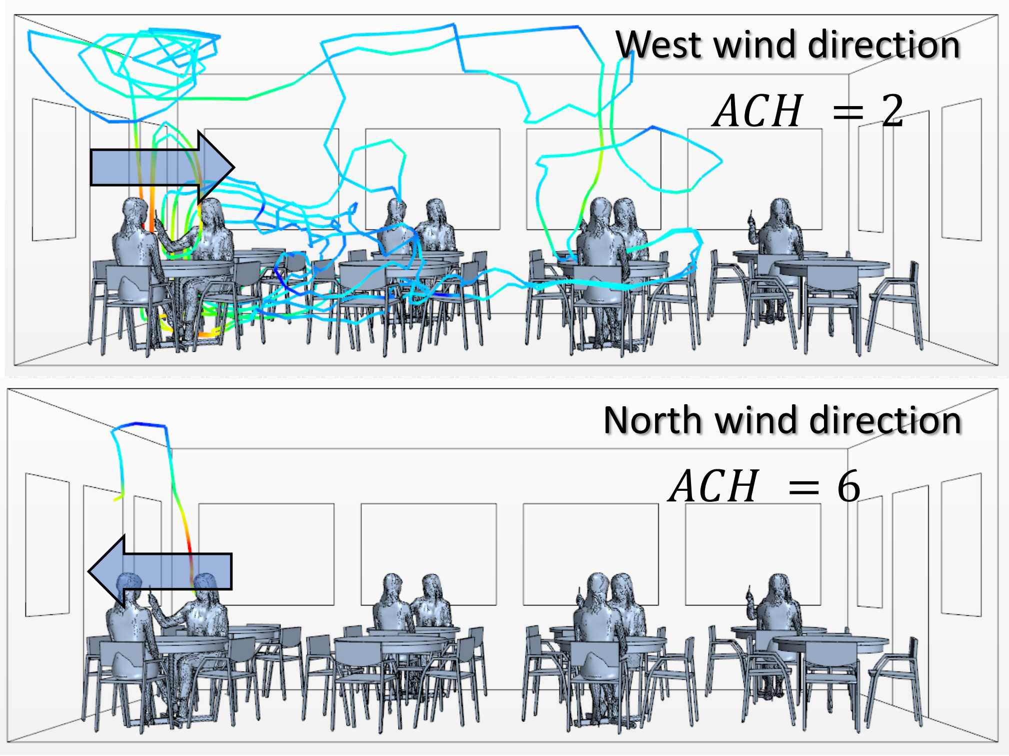
Low differences

*Chang & Hanna, 2004

Wind direction effect on the volume average of ΔC_{CO_2} incoming to P_i from the others

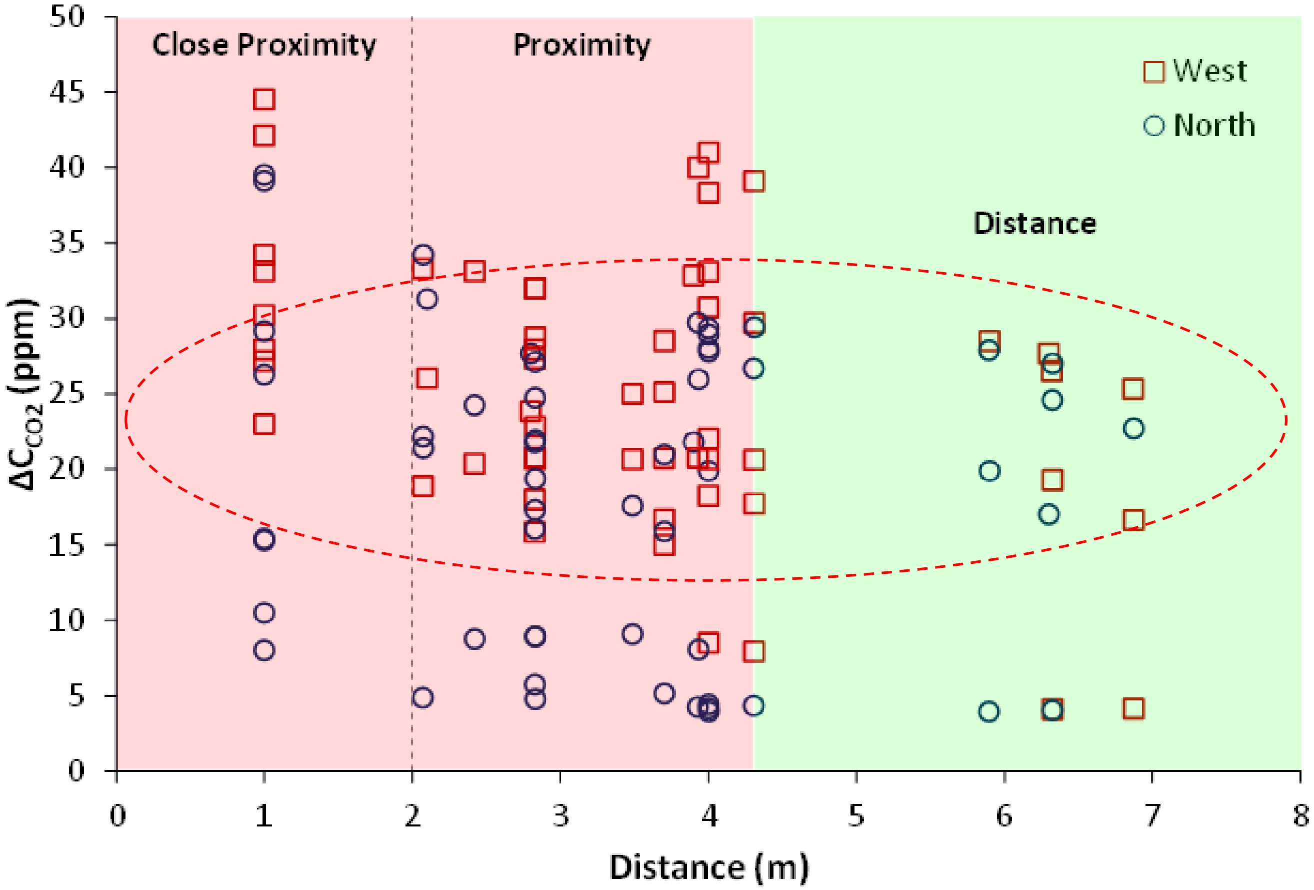
Streamlines from P1´s mouth to the outlet during the steady state





Single-Sided Ventilation

Volume average of ΔC_{CO_2} incoming to P_i from the others during the steady state



In poorly ventilated scenarios, measures based on the social distance between people have a negligible impact to reducing the cross-infection risk