Estimation of the risk of airborne transmission in an elementary school classroom through Large Eddy Simulation

A. Vignolo*, M. Draper* and G. Usera*
Corresponding author: avignolo@fing.edu.uy

* Instituto de Mecánica de los Fluidos e Ingeniería Ambiental,
Facultad de Ingeniería, Universidad de la República, Uruguay.

Abstract: The pandemic of COVID-19 has had a major impact globally. Several authors have argued that the airborne transmission route of the virus SARS-CoV-2 plays a major role, particularly in poorly ventilated indoor environments. The risk of airborne transmission of SARS-CoV-2 in an elementary school classroom is estimated through highly resolved Large Eddy Simulation, considering different situations characterized by ventilation rate, quanta emission and openings configuration. The developed numerical framework is able to capture the dynamic of the phenomenon, highlighting the importance of the spatial and temporal inhomogeneities.

Keywords: SARS-CoV-2, Airborne Transmission, Large Eddy Simulation.

1 Introduction

The pandemic of COVID-19 has had a major impact globally. Particularly during the first waves of the pandemic, non-pharmaceutical interventions were applied in different regions worldwide, including school closures, totally or partially.

Several authors have argued that the airborne transmission route of the virus SARS-CoV-2 plays a major role, particularly in poorly ventilated indoor environments [3]. To assess the risk of airborne transmission, different tools have been applied, from analytical models to higher fidelity models based on Computational Fluid Dynamics (CFD) simulations. CFD codes have been applied to different scales of the problem, from simulating the dynamics of droplets during violent expiratory events, like sneezing or coughing, to simulating the airborne transmission in relatively large indoor environments.

The aim of the present paper is to develop a numerical tool to estimate the risk of indoor airborne transmission given a defined ventilation condition and its application to an elementary school classroom.

2 Method

A classroom in an elementary school in Uruguay has been selected to assess the risk of airborne transmission through CFD simulations with the code chaman. chaman is an open source finite volume code, second order accurate in space and time, developed recently by expanding the in-house flow solver caffa3d to use CPU-GPU infrastructure. Details about caffa3d can be found in

[2]. Carbon dioxide (CO_2) and quanta emissions are considered in the simulations. The balance equations are solved using the Large Eddy Simulation (LES) method.

The classroom size, and hence the computational domain dimension, is 8 m $\times$ 6 m $\times$ 3.45 m. A structured collocated grid composed of structured grid blocks is used. It is uniformly divided into $950 \times 756 \times 382$ inner cells, comprising around 283 million grid cells. Therefore, the spatial resolution is 0.0084 m $\times$ 0.0079 m $\times$ 0.0090 m respectively, slightly finer than the one used in [1].

The classroom is naturally ventilated. It has 4 windows at its west wall and 1 upper window and 1 door at its east wall. Different ventilation rates, openings configurations and position of the infector are simulated. The representation of students and teacher is accomplished by using the immersed boundary method.

To compute the risk of airborne transmission, the approach presented in [1] is used. These results are compared with the ones obtained with the Wells-Riley formulation as done by the authors.

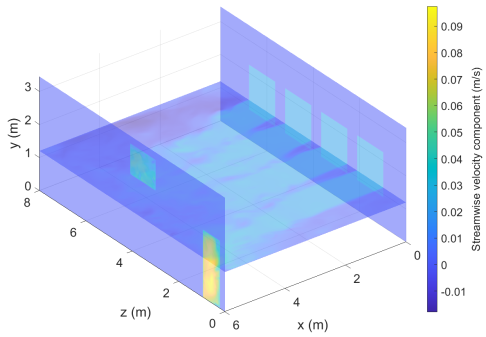

Figure 1: Instantaneous streamwise (x direction) velocity component at a horizontal plain 1.20 m above the floor without students and teacher. Ventilation rate: 3ACH.

3 Conclusion and Future Work

The risk of airborne transmission of SARS-CoV-2 in an elementary school classroom is estimated through highly resolved Large Eddy Simulation, considering different situations characterized by ventilation rate, quanta emission and openings configuration. The developed numerical framework is able to capture the dynamic of the phenomenon, highlighting the importance of the spatial and temporal inhomogeneities. As future work, instead of simulating the quanta emission as a tracer gas, a lagrangian formulation will be implemented to model the droplets dynamics.

References

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