Validation and Application of Lagrangian Stochastic Methods for Indoor Air Quality

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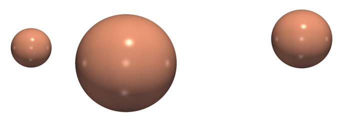
The project

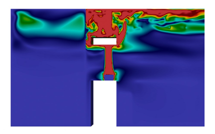
- Computational Fluid Dynamics (CFD) simulations are used to replicate fine particulate matter ($PM_{2.5}$) dispersion from a cooking pot in the DOMESTIC air quality test house. Various ventilation scenarios are tested. The validated CFD model will ultimately feed data back into the experimental work at DOMESTIC.

Tracking $PM_{2.5}$ dispersion



2.5 μm or less in diameter

- It may be invisible to the naked eye, but $PM_{2.5}$ is a serious health hazard. Regular exposure to concentrations of over **15 μg m^{-3}** is correlated with an increased risk of chronic obstructive pulmonary disorder (COPD), coronary heart disease, stroke, and lung cancer [1]. But cooking activities can cause local $PM_{2.5}$ concentrations of more than **350 μg m^{-3}** [2].
- Lagrangian particle tracking is highly computationally intensive, but enables individual particle trajectories to be calculated. Hence it is very suitable for air quality studies.

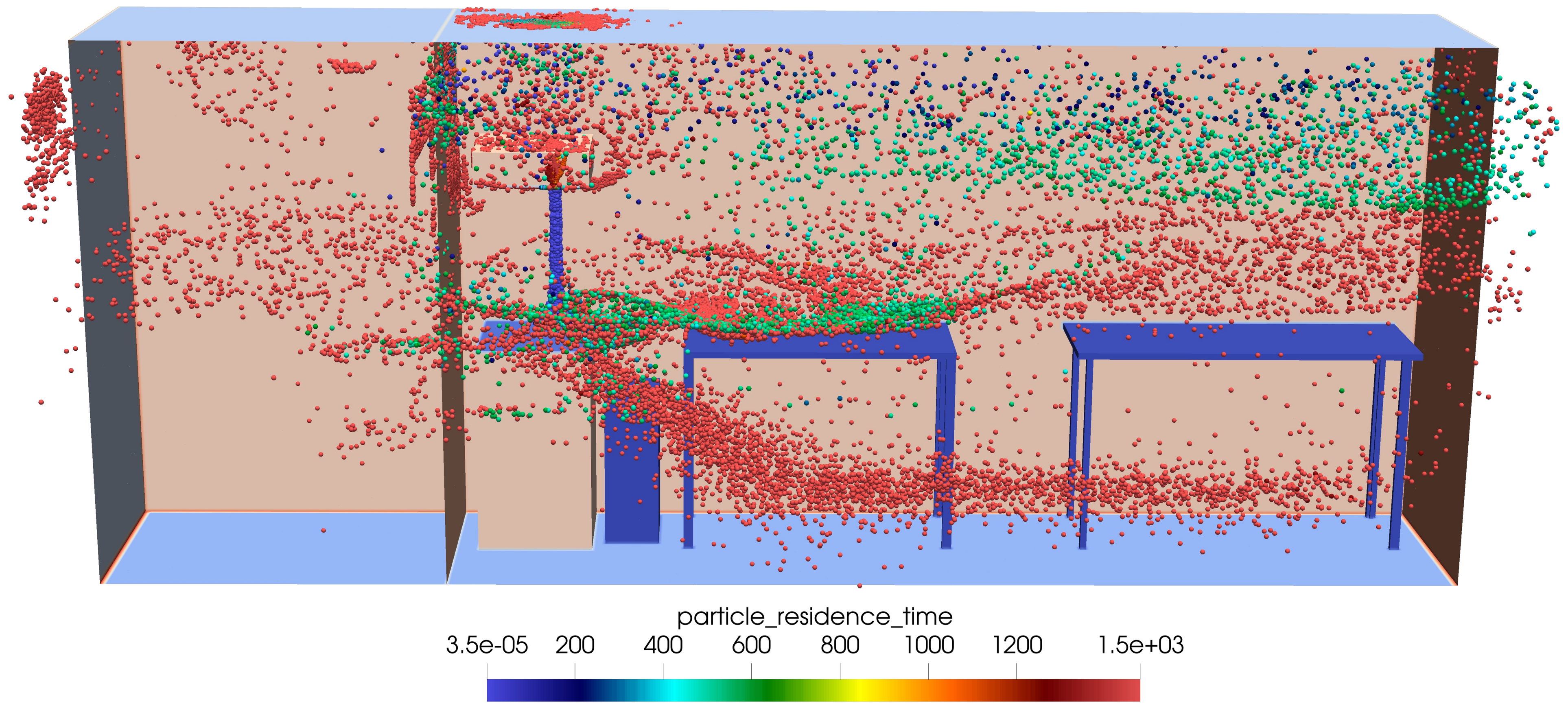


Code_Saturne

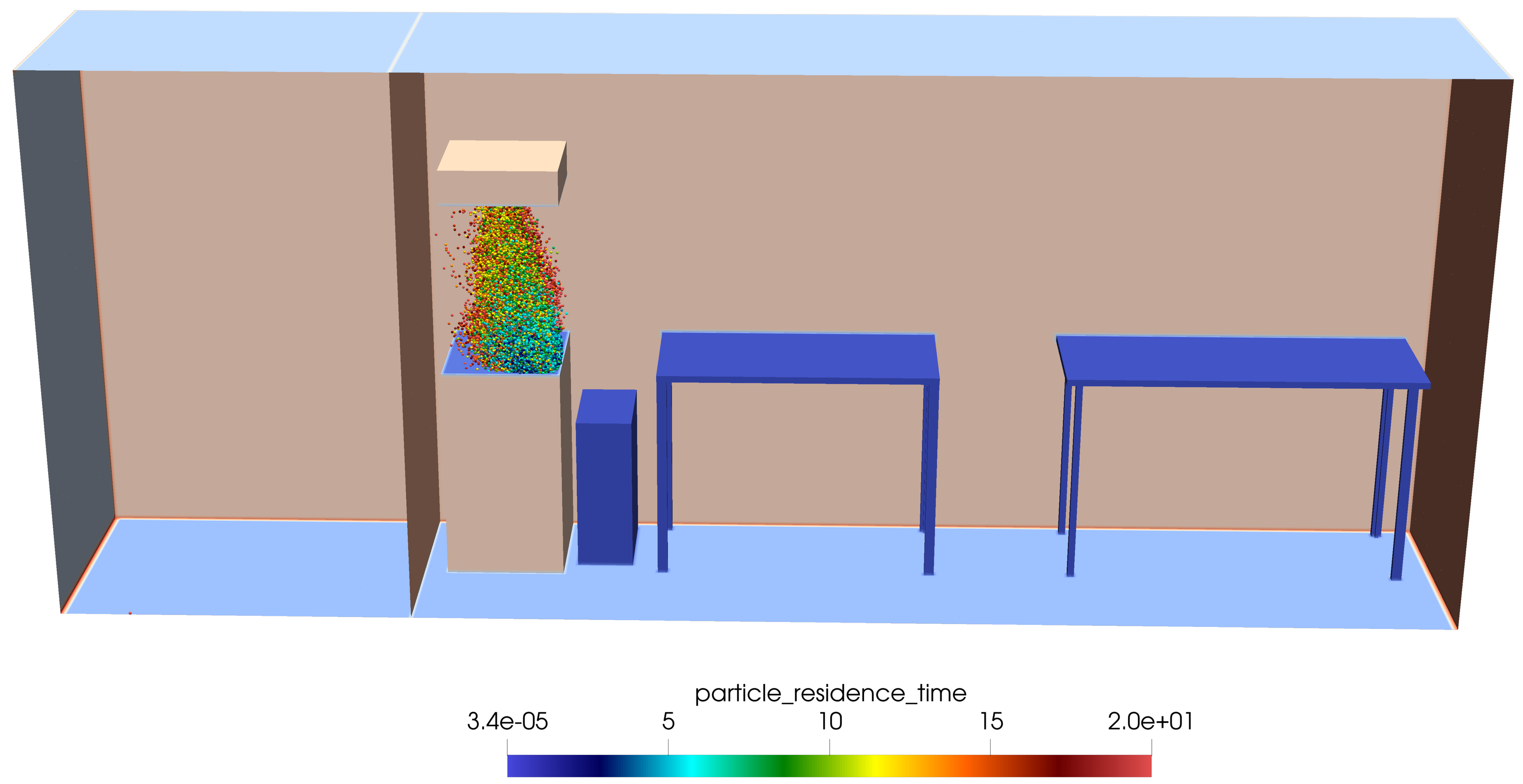
- Calculations have been performed using the open source CFD solver *Code_Saturne,* which is based on a finite volume discretisation. Second order central differencing is used for the convective terms, whereas an implicit Euler scheme is used for the time advance. The solver also includes a Lagrangian Particle Tracking (LPT) module [3].

Initial results – impact of ventilation on kitchen $PM_{2.5}$ concentrations during cooking

No ventilation…

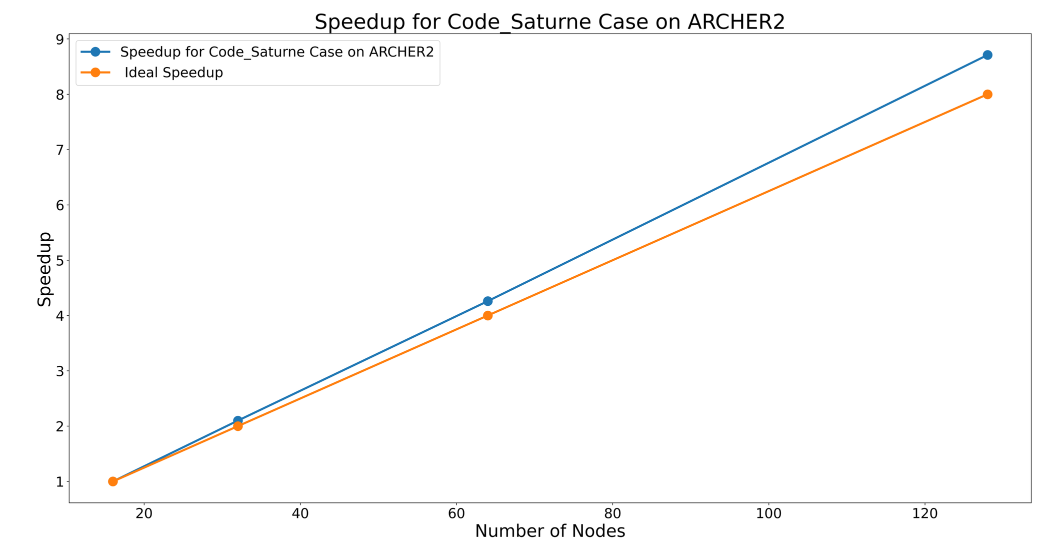


Versus hood extractor fan on (375 m^3hr^{-1})

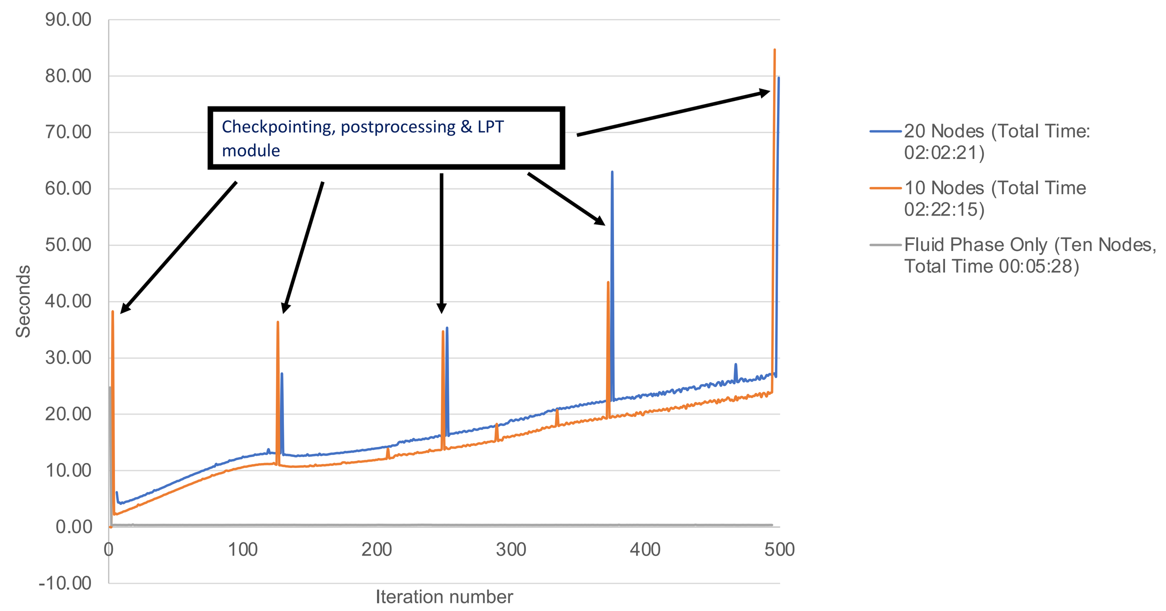


Cases use a ten million cell mesh, the EBRSM turbulence model and one-way fluid-particle coupling. 10,000 particles were injected per second, with a statistical weighting of 100. Simulations were run for 25 in-simulation minutes on twenty 32-core AMD nodes on STFC's Scientific Computing Application Resource for Facilities (SCARF) cluster.

Efficiency



- *Code_Saturne* scales excellently, with project cases showing a super-ideal speedup over a 16 -128 node range on ARCHER2. (Time step: 0.005 s, mesh size: 130 million cells)



- Efficient parallelization relies on the number of particles in the domain. Over the first 500 iterations of the case above, 20 nodes gave a 20-minute reduction in compute time, but the majority of iterations were slightly slower than for the 10-node case.
- It may be more energy efficient to initially run on fewer nodes, restarting on a higher number once the particle load is sufficiently high.

Acknowledgements

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References

[1] World Health Organisation, **2021**, *WHO Air Quality Guidelines.* [2] Y. Omelekhina et.al., *Environmental Science: Processes & Impacts* **2020**, 22, 1382-1396. [3] *Code_Saturne,* **2022, https://www.code-saturne.org/cms/web/**