Oral presentation | Turbulence simulation (DNS,LES,RANS)
Turbulence simulation(DNS,LES,RANS)-I
Wed. Jul 17, 2024 2:00 PM - 4:00 PM Room B

[8-B-02] Large Eddy Simulation in the Indoor Vertical Farming modelling

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Keywords: Large Eddy Simulation, Vertical Farming simulation, Carbon Dioxide propagation, Buoyancy

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LARGE EDDY SIMULATION IN THE INDOOR VERTICAL FARMING MODELLING

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Vertical Farming Concept

- Enclosed cultivation systems with high controllability
  Artificial lighting
- Soilless cultivation method
- Without natural ventilation

- High water efficiency
- High land use efficiency
- Independence from seasonal and geographical limitations

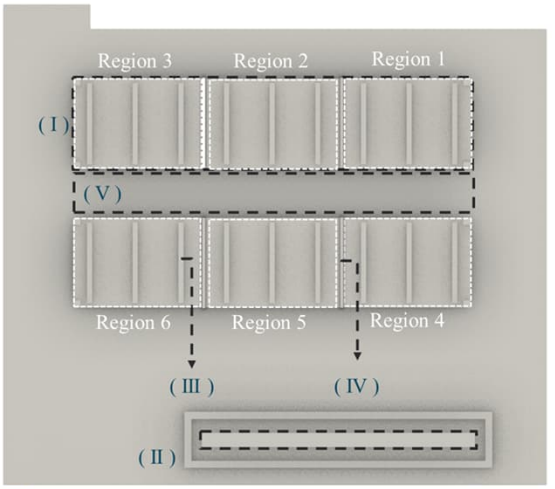
In this study

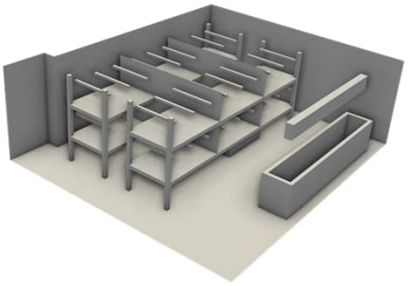
LES approach
K-equation modeling

Eulerian-Lagrangian Free fall droplets

Transpiration and Photosynthesis modeling

Heat transfer Simulation





I)	Canopy tray	Humidity source, CO2 sink
II)	Dehumidifier	Sink of enthalpy, Sink of humidity, Source of Eulerian-Lagrangian water droplets
III)	Lamps	Constant heat flux
IV)	Curtains	Air manipulators, acts as walls
V)	CO2 distributor pipe	CO2 Source
VI)	Inlet Fan	Uniform velocity input

Region 1 to 6: Location of the samples in LUKE experiment divided by the baffles

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\frac{\partial}{\partial t}(\rho \mathbf{u}) + \nabla \cdot (\rho \mathbf{u}\mathbf{u}) = -\nabla p + \rho g + \nabla \cdot \left(2\mu_{eff} D(\mathbf{u})\right) - \nabla\left(\frac{2}{3}\mu_{eff}(\nabla \cdot \mathbf{u})\right) + \rho \mathbf{F}$$

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot (\rho \mathbf{u} h) + \frac{\partial}{\partial t}(\rho K) + \nabla \cdot (\rho \mathbf{u} K) - \frac{\partial p}{\partial t} = -\nabla \cdot \mathbf{q} + \nabla \cdot (\tau \cdot \mathbf{u}) + \rho r + \rho \mathbf{g} \cdot \mathbf{u}$$

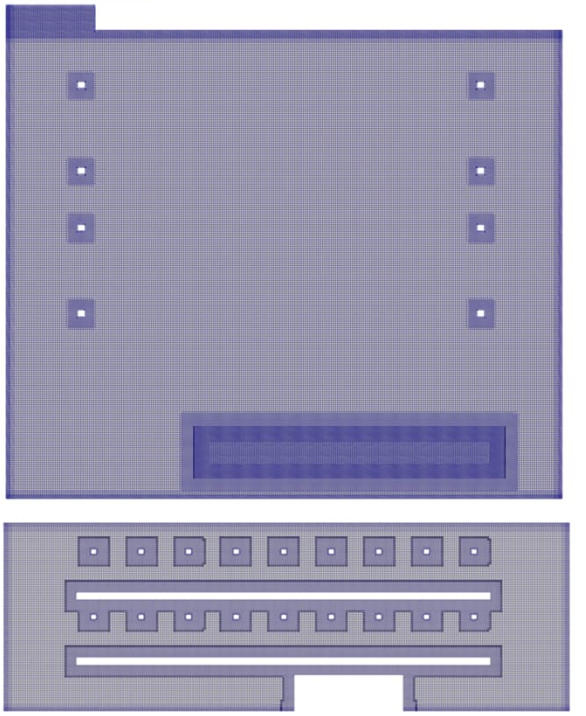
$$\frac{\partial c}{\partial t} + \nabla \cdot (c\mathbf{u}) = \mathrm{D}\nabla^2(c)$$

$$\mathrm{F_D} = \frac{3}{4}\frac{\mu_c \mathrm{C_D Re}_p}{\rho_p d_p^2}$$

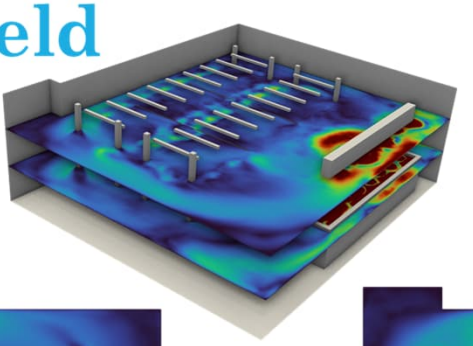
Grid Resolution

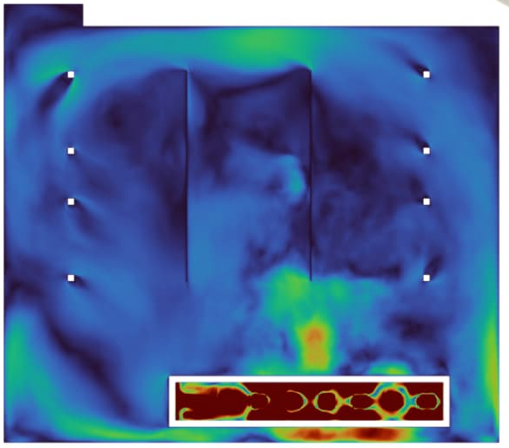
Fine Grid: 32,173,872
Medium Grid: 14,141,949
Coarse Grid: 7,283,097

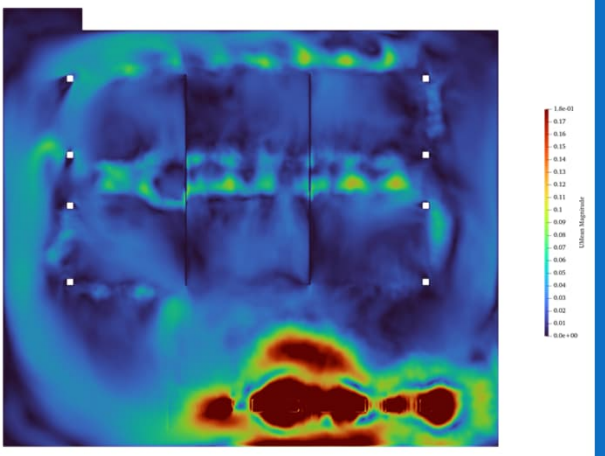
Mesh Comparison Deviation	
Coarse and Medium (Tray 1)	1,10 %
Medium and Fine (Tray 1)	0,82 %
Coarse and Medium (Tray 2)	0,76 %
Medium and Fine (Tray 2)	0,50 %
Coarse and Medium (Horizontal)	0,96 %
Medium and Fine (Horizontal)	0,41 %



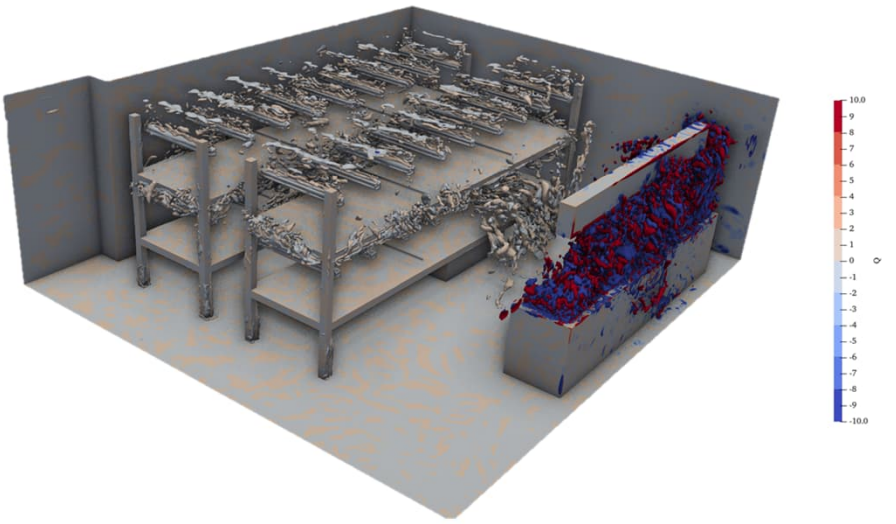
Velocity Field



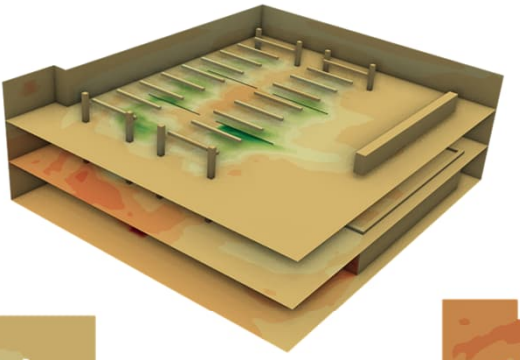


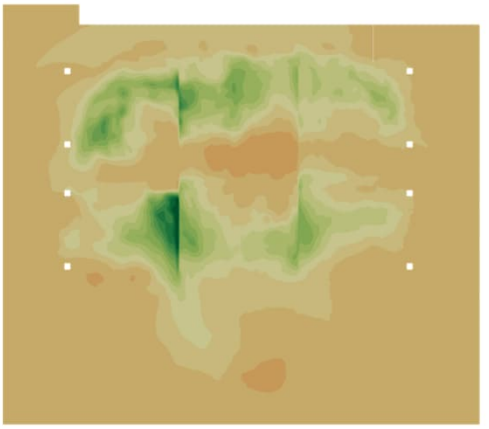


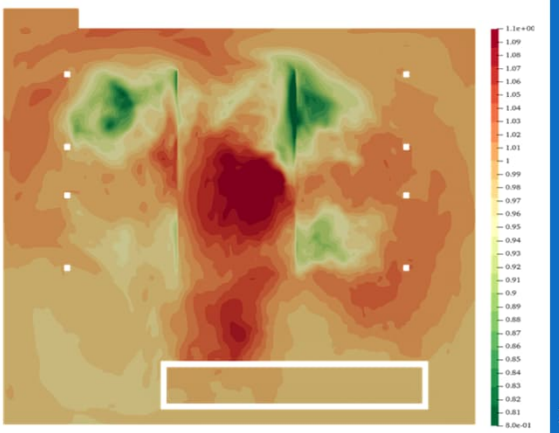
Q criterion



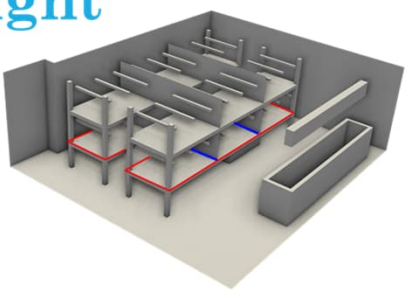
CO_2 Field

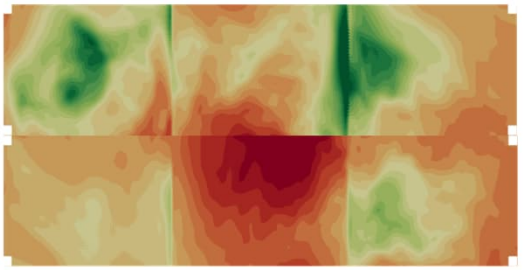


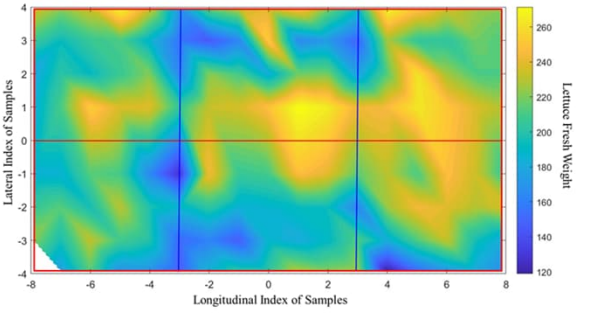



1.1e+00
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0.89
0.88
0.87
0.86
0.85
0.84
0.83
0.82
0.81
8.0e-01

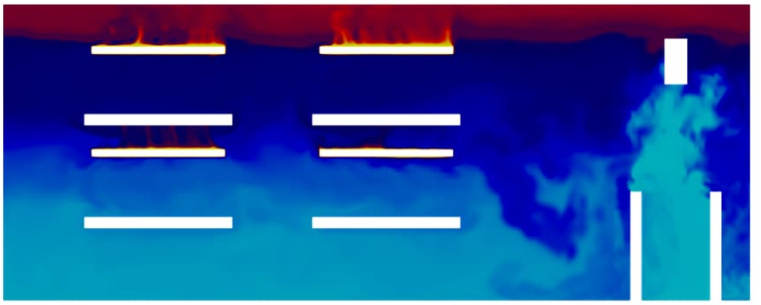
Correlation of CO_2 and Lettuce fresh weight

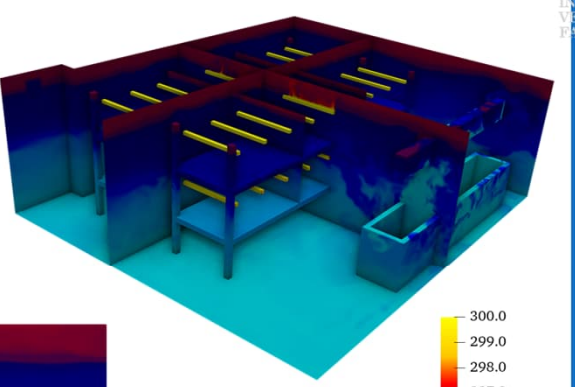


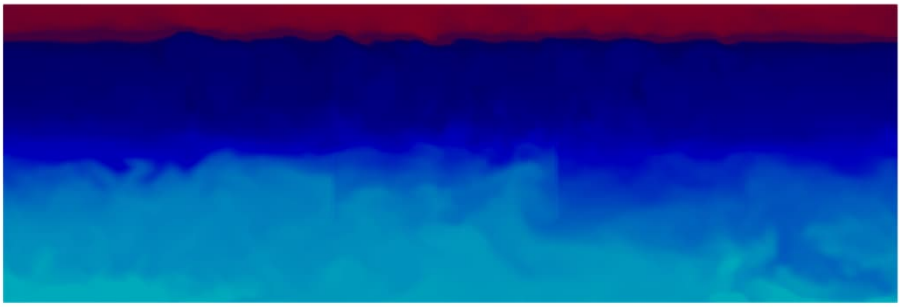


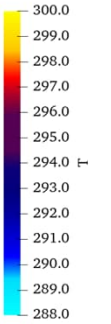


Temperature Field









Concluding remarks

- The correlation of experimental results and the flow field characteristics in the simulations manifest the capability of LES in the simulation of Vertical Farming system
- The implementation of curtains, reduces the accumulation of CO_2 in the vicinity of them
- The second level of trays unfavorably has less CO_2 in the simulations, which suggest improvement in the CO_2 injector utility in the system.

Thank you for your attention