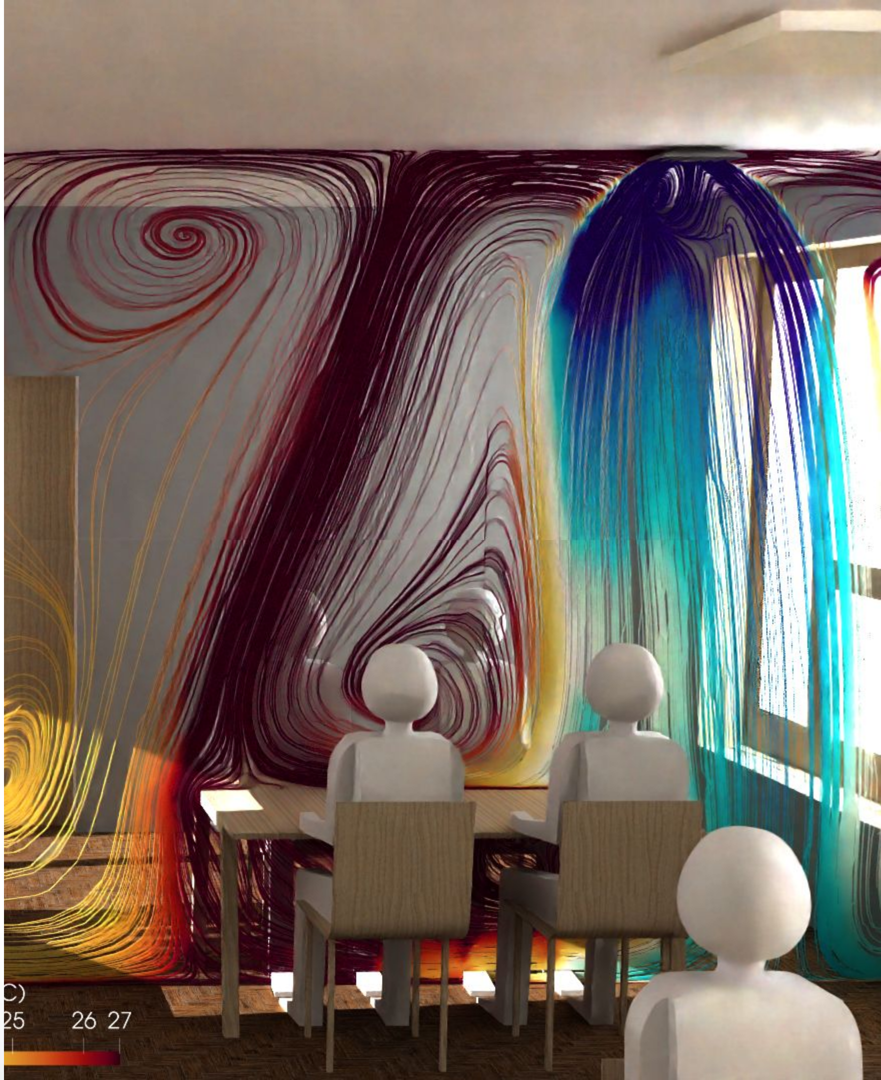
Simulating Thermal Comfort and the Outdoor Environment

Dr. Naghman Khan and Darren Lynch (SimScale)

For CIBSE North East 12 Jan 2021

Contact: nkhan@simscale.com



Dr. Naghman Khan

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Experienced in simulation, Naghman has a PhD in building simulation and is a co-founder of the CIBSE Building Simulation Group (UK). He is part of the business development team at SimScale.

Darren Lynch

CFD Application Engineer

Experienced in CFD and engineering design, Darren studied Aerospace Engineering at Brunel University and is a part of the application engineering team at SimScale.

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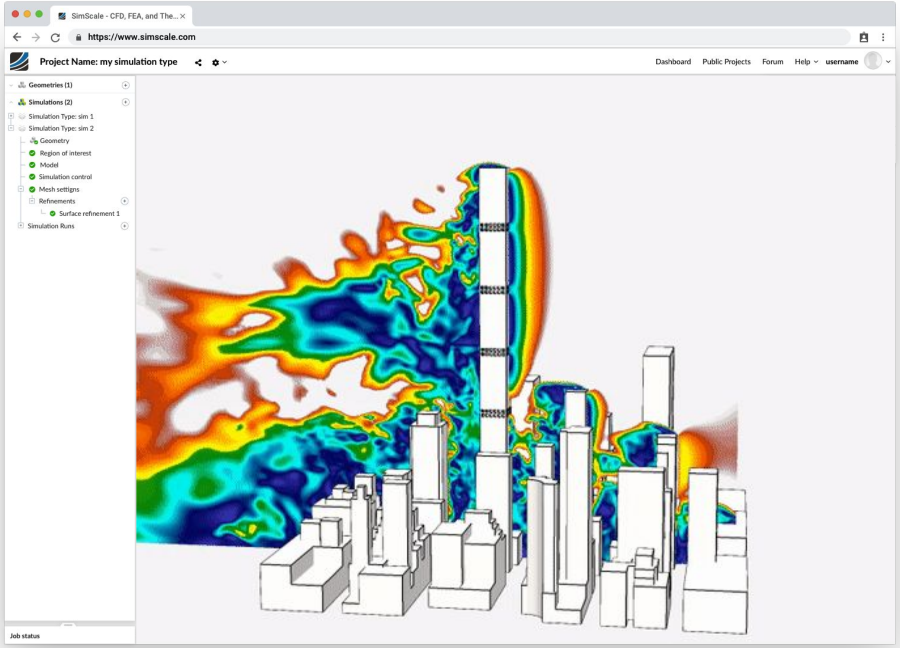


About SimScale

What we do

We created the world's first cloud-based engineering simulation platform.

- Fluid dynamics (CFD)
- Solid mechanics (FEA)
- Thermodynamics

All accessible via a web browser.

Agenda

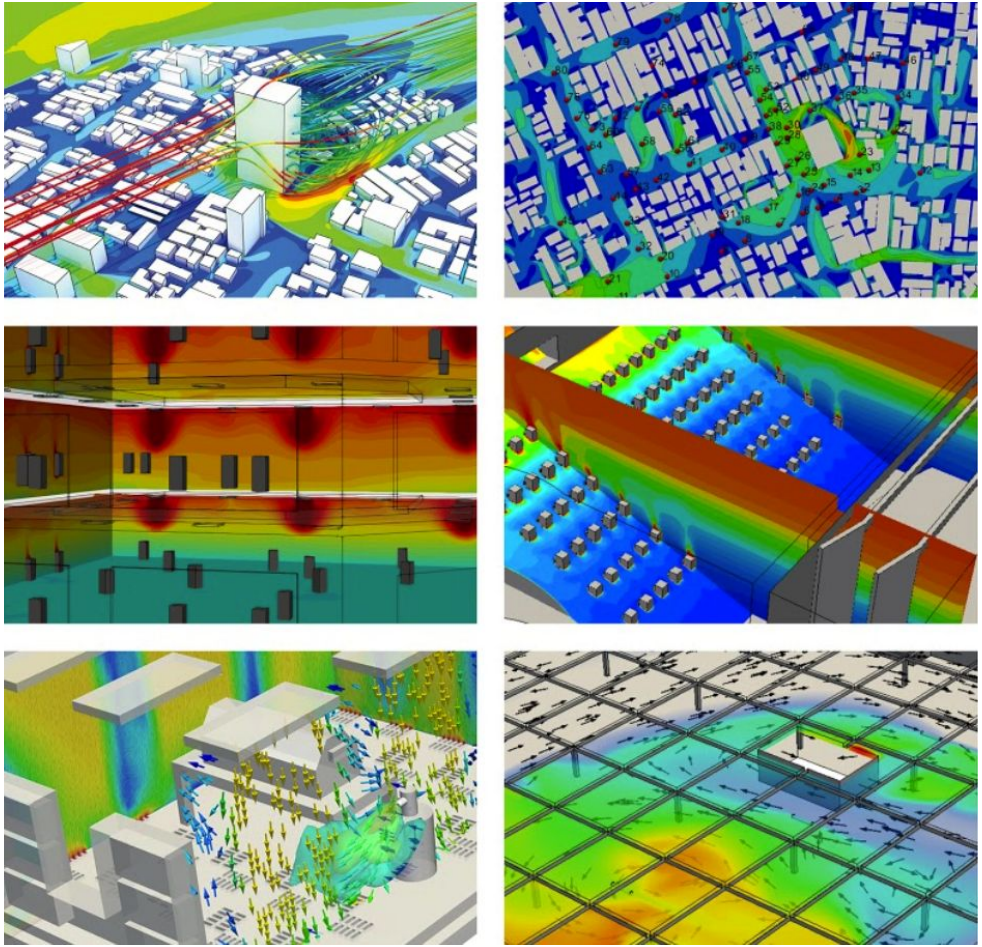
1. Cloud Simulation
2. Thermal comfort and Ventilation Modelling
3. Building Aerodynamics and Wind Comfort
4. Q&A

Simulating Thermal Comfort and the Outdoor Environment

Cloud Simulation - Live Demo

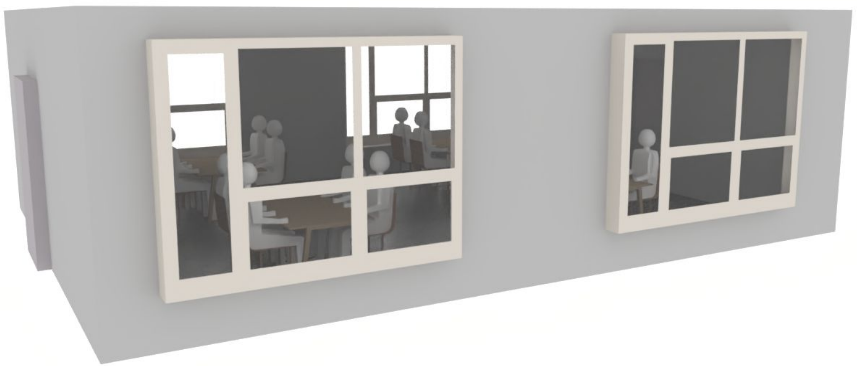
Simulating Thermal Comfort and the Outdoor Environment

Thermal Comfort & Ventilation Modelling



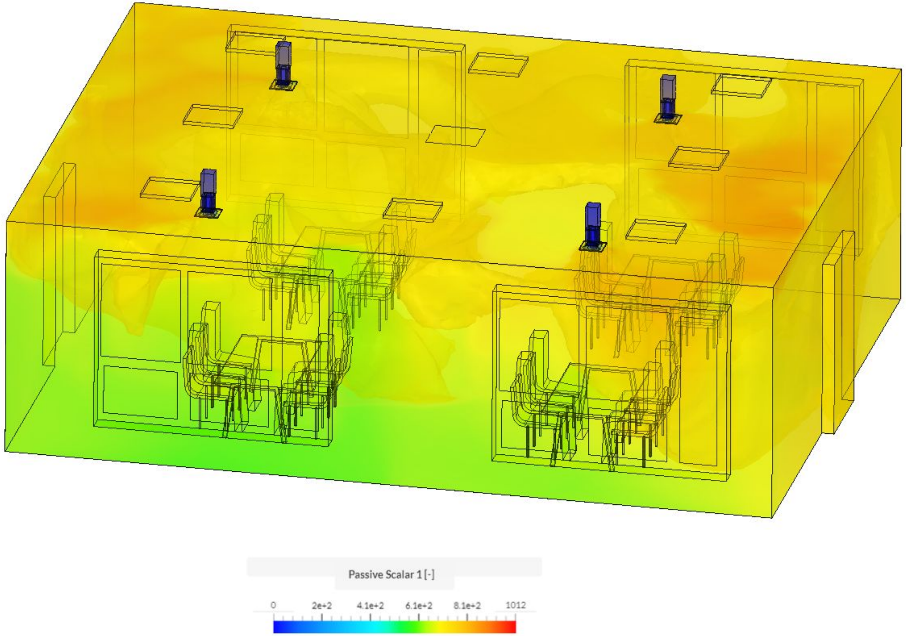
Thermal Comfort & Indoor Environment

1. Natural and mechanical ventilation
2. Thermal comfort & compliance with standards
3. Indoor air quality
4. Contamination spread and control
5. Smoke propagation & extraction



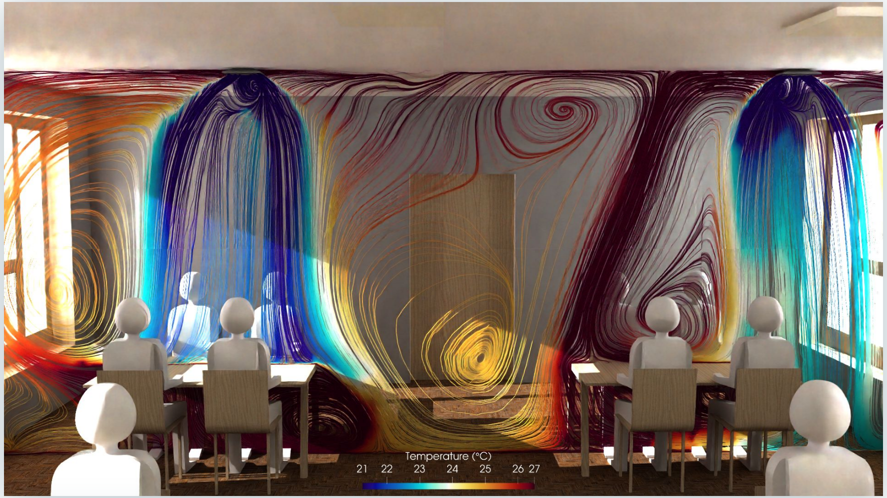
Ventilation Modelling

- Simulate multiple scenarios for window openings and mechanical supply/extract
- Import CAD model
- Define boundary conditions
- Simulate on the cloud—multiple models can be simulated in parallel



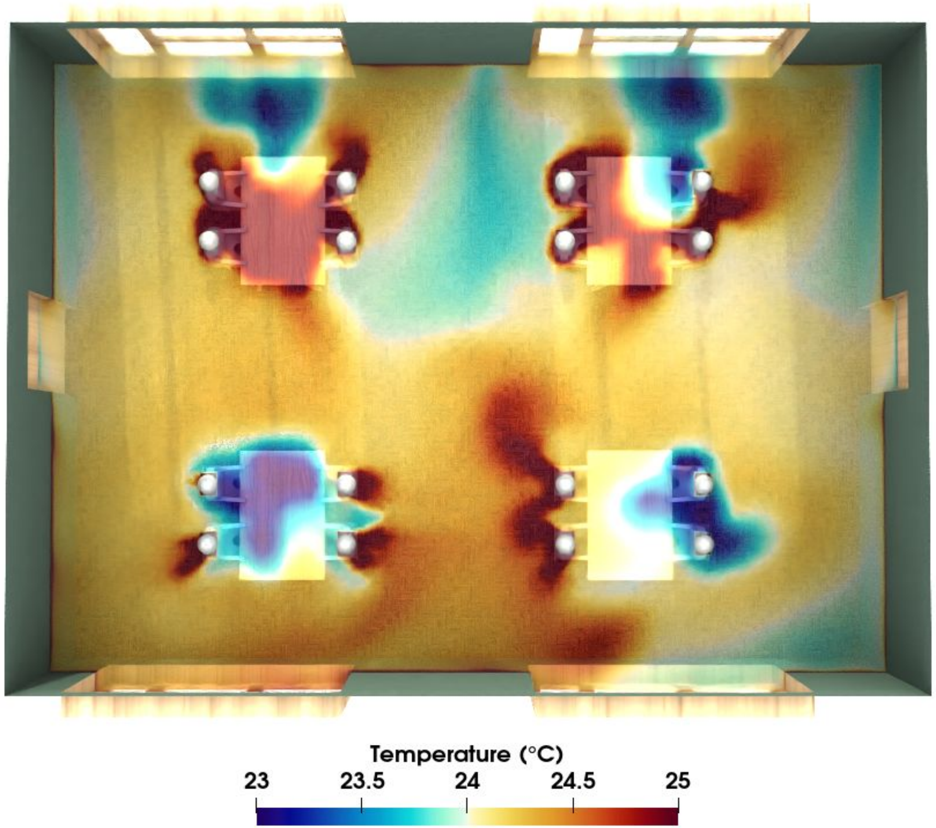
Ventilation Modelling

- Room level outputs of ventilation
  - ACH
  - Mean Age of Air
  - At various points (Head height)
  - Comparison of scenarios



Ventilation Modelling

- Visualise air flow distribution and patterns:
  - Air velocity
  - Temperature
- At various planes and locations
- Compare what opening another window does to the room air flow pattern



Ventilation Modelling

- Working height temperature distribution
- Thermal comfort parameters
- Vary supply and ambient temperature
- Vary heat gains
- Evaluate draughts and gusts

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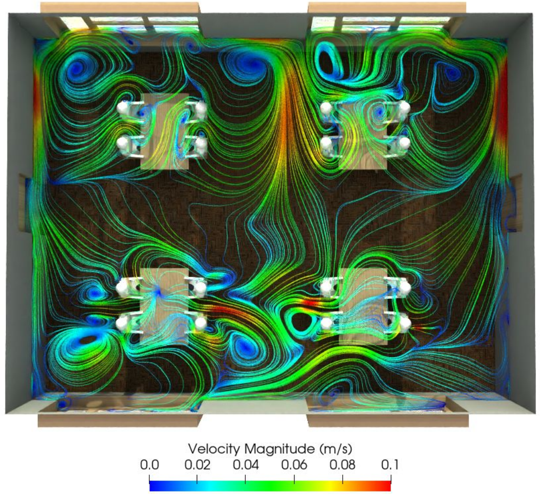

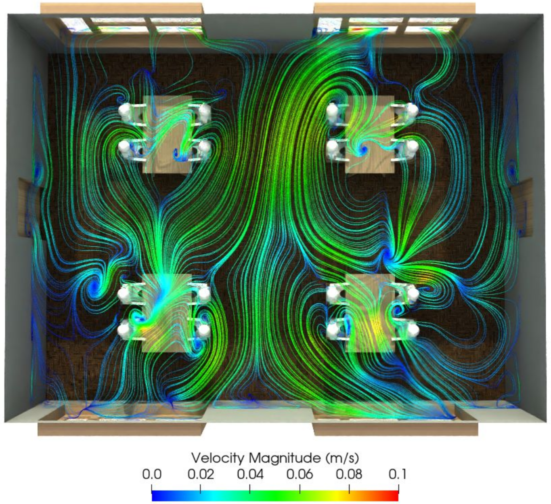

Ventilation Modelling

- Simulate multiple scenarios for window openings and mechanical supply/extract
- Comparing the two options we can see windows closed (top) and windows open (bottom) and variation in room velocity magnitude at head height
- CFD for Ventilation Design

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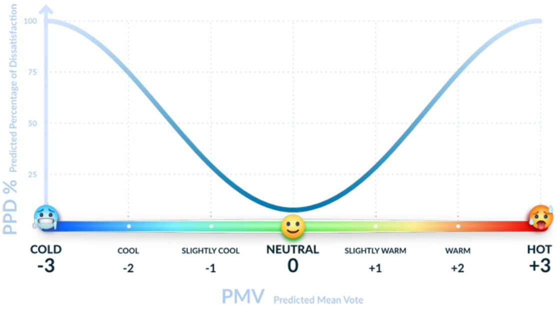
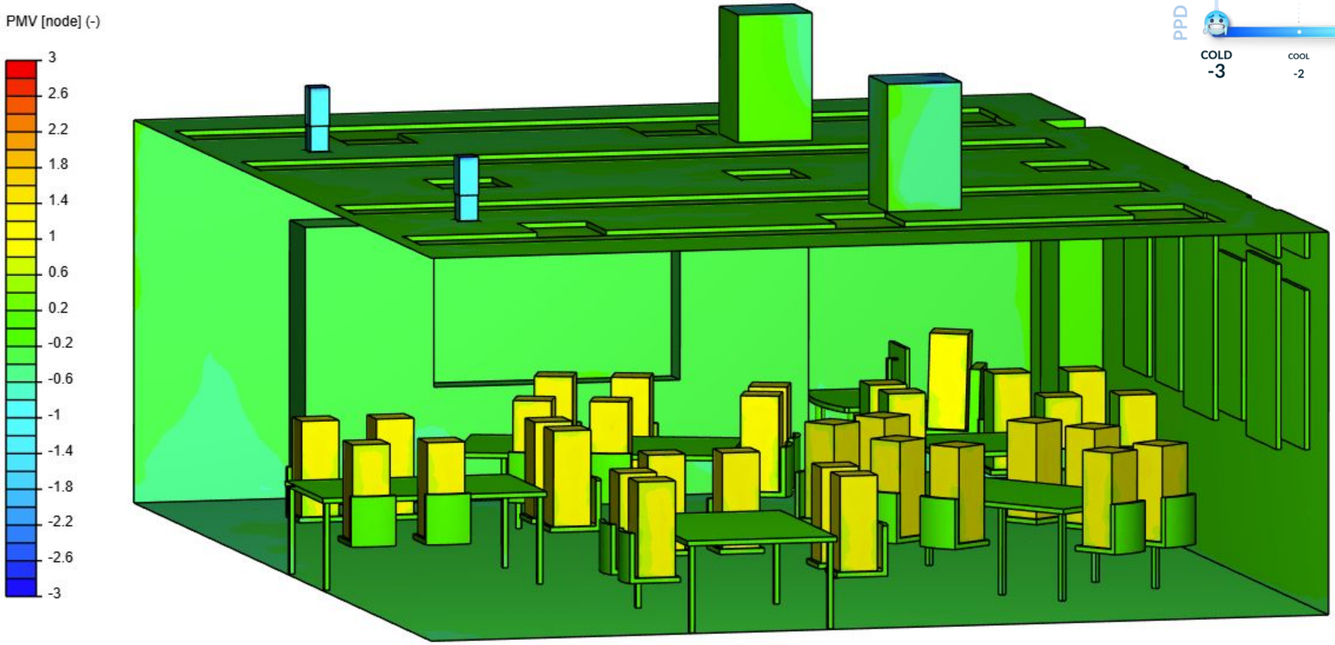
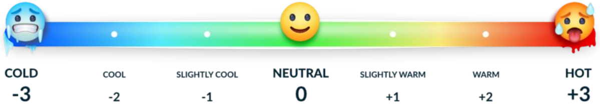
Predicted Mean Vote (PMV)

Within the PMV index, +3 translates as too hot, while -3 translates as too cold.







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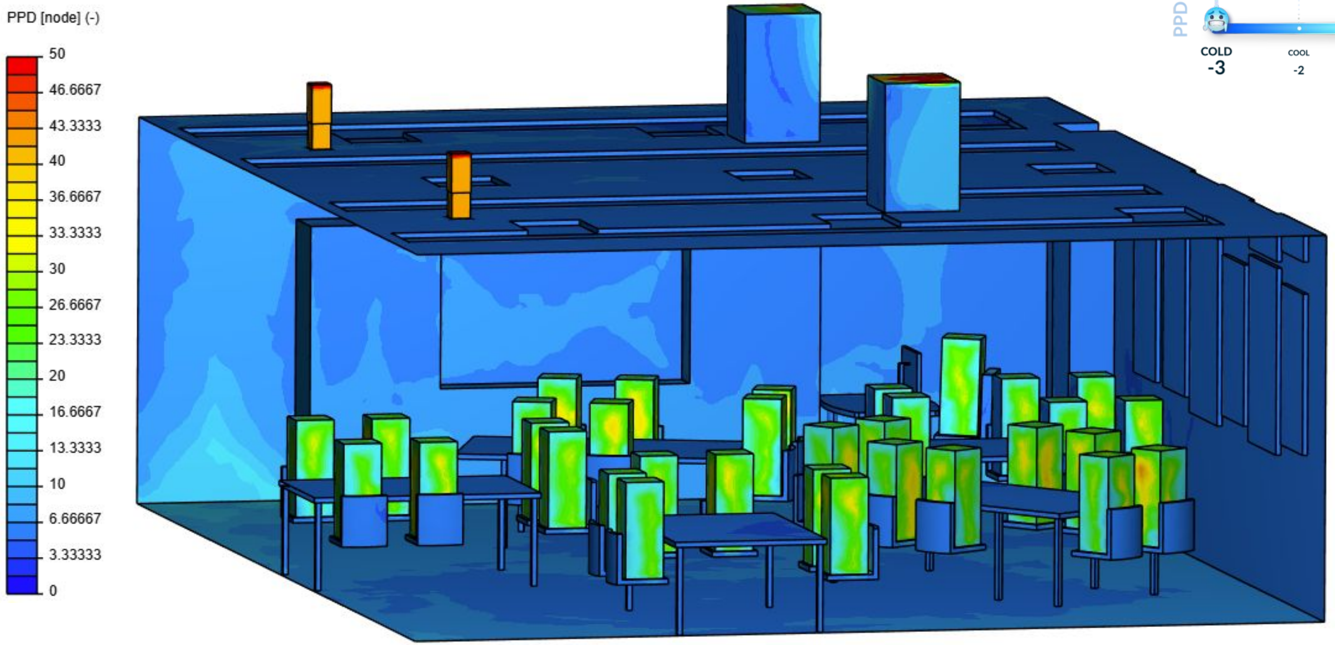
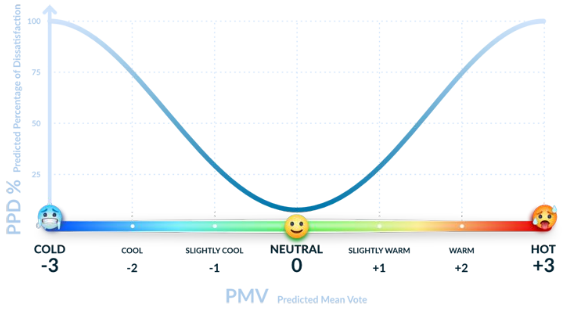
Predicted Percentage of Dissatisfied (PPD)





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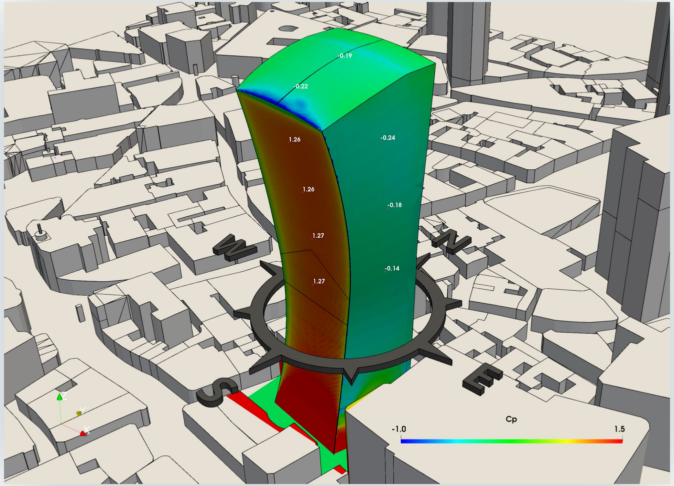
Why are Wind Pressure Coefficients (Cp) So Important?

1. The wind pressure at an opening (Pw) and hence ΔP - difference between internal and external pressure determines how building simulation tools calculate air flow (natural ventilation, fresh air etc.) through windows/openings.

2. This air exchange will have a ΔT - difference between internal and external temperature

3. Therefore the amount of air coming in/out of openings has a direct impact on building:
    a. **Fresh air and air exchanges** - are you calculating the ventilation and air quality values correctly?
    b. **Heating and cooling loads** - because the amount of air coming in/out of your building at a certain temperature will either add or remove thermal energy from your spaces
    c. **Energy** - Gas and electricity due to heating and cooling costs
    d. **Thermal comfort** - air speed, distribution, temperature and quantity of flow rate.



$$p_w = C_P \frac{1}{2} \rho v^2$$

where

p_w is wind pressure (Pa)

C_p is wind pressure coefficient

ρ is air density (kg/m ^{3})

v is a reference wind speed (m/s)

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What Factors Should You Watch Out For?

Most thermal modelling and building simulation tools use simple airflow network models to calculate bulk air movement. They **DO NOT** capture the following effects:

- Wind turbulence
- External wind conditions
- Local building context
- Terrain is an oversimplified constant
- Exposure types are poorly understood and seldom applied. They are also based on very simplified wind tunnel testing conducted a long time ago.

Have you ever thought of how your wind pressure coefficients can be more accurately calculated?

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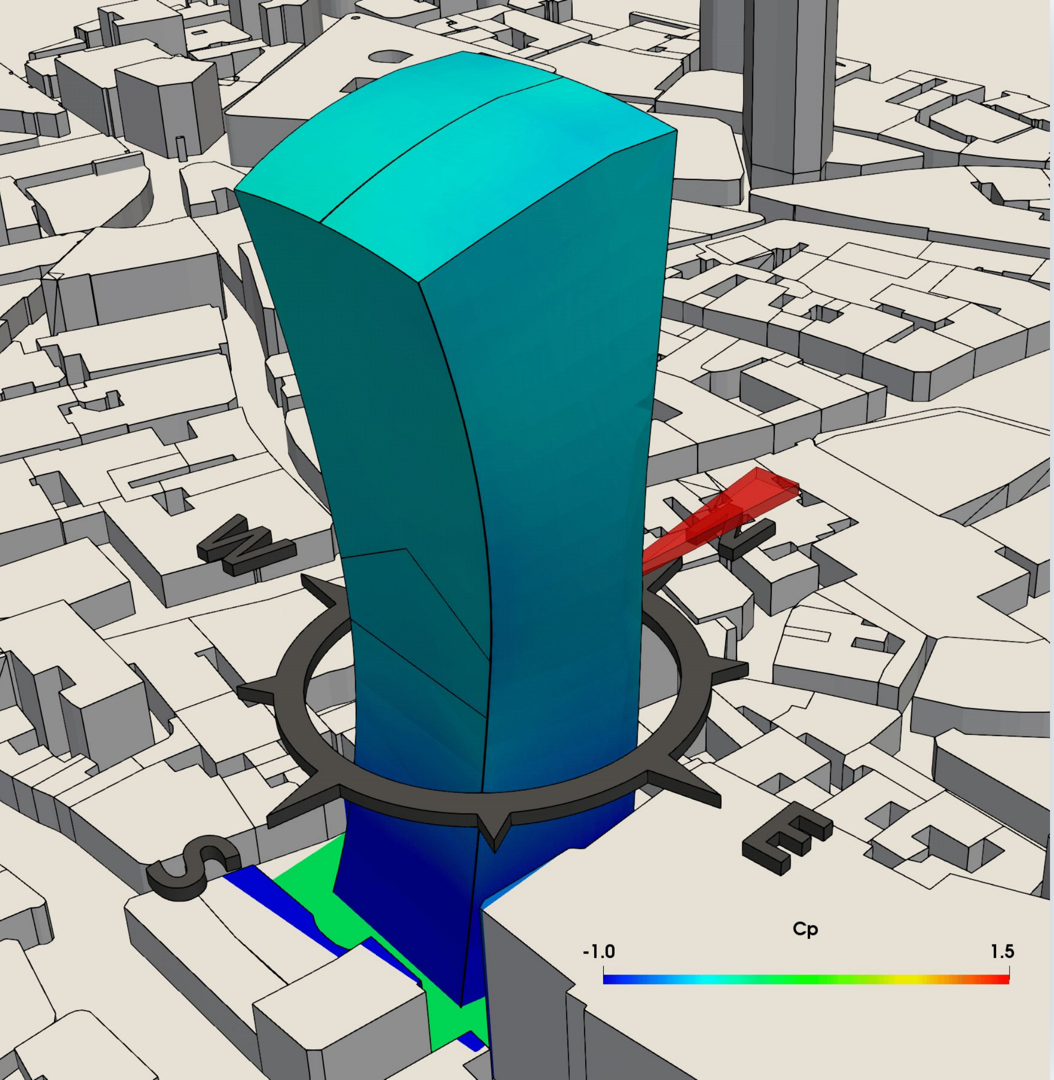
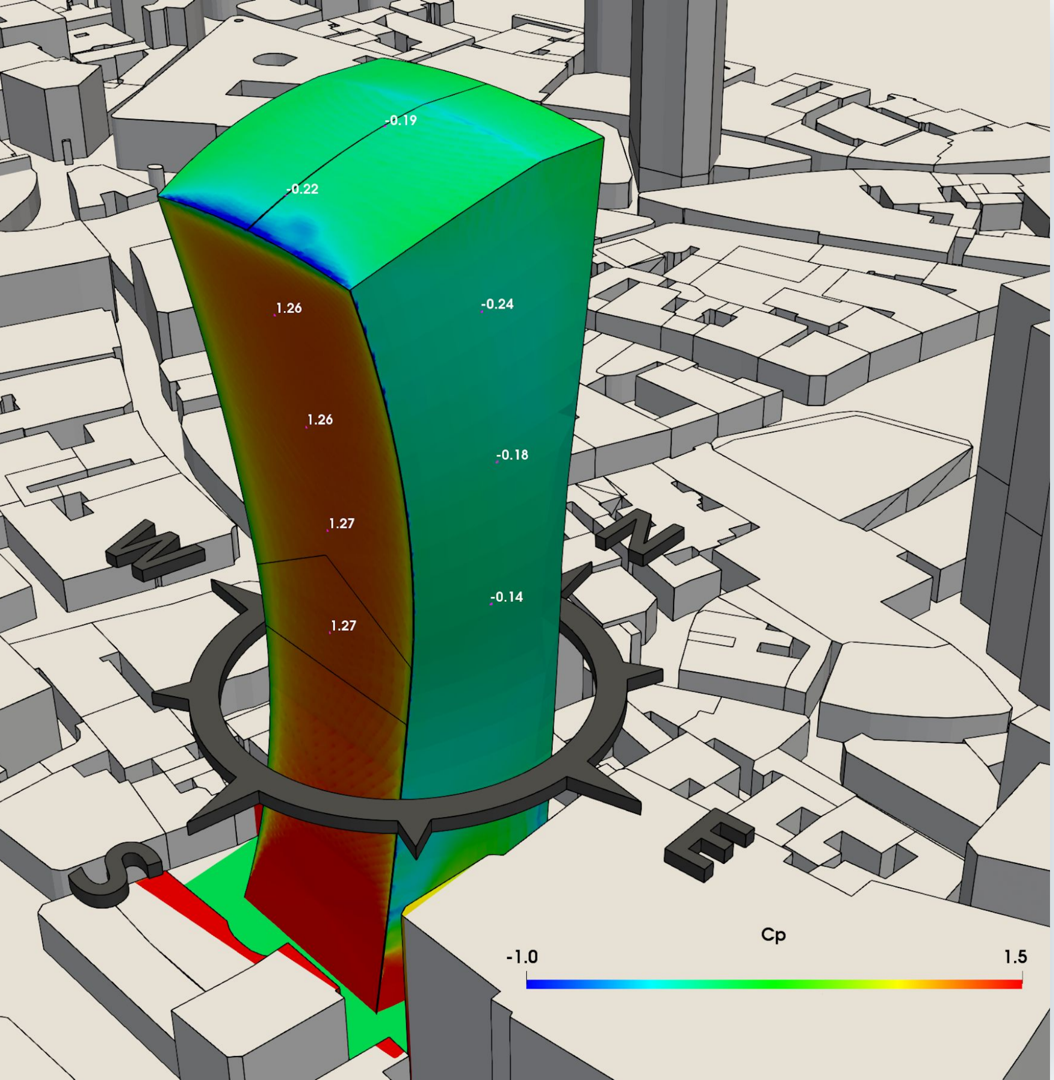


16 Directions, At Once!

- All these wind directions are computed in parallel, a transient (real-time wind) simulation takes less than 2 hours.
- Results are exported on the building surfaces.



Import Into Thermal Modelling Software

These pressure coefficients can then be used for a plethora of purposes—including increasing the accuracy of thermal models.

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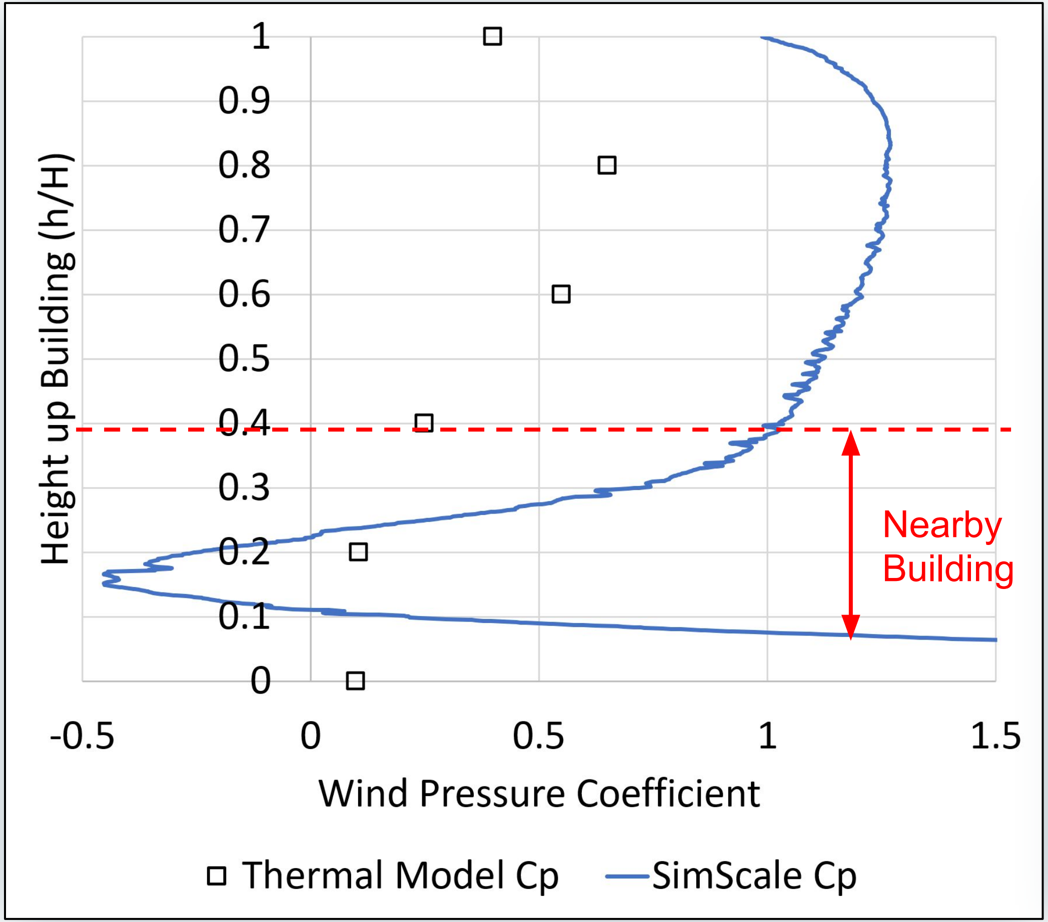
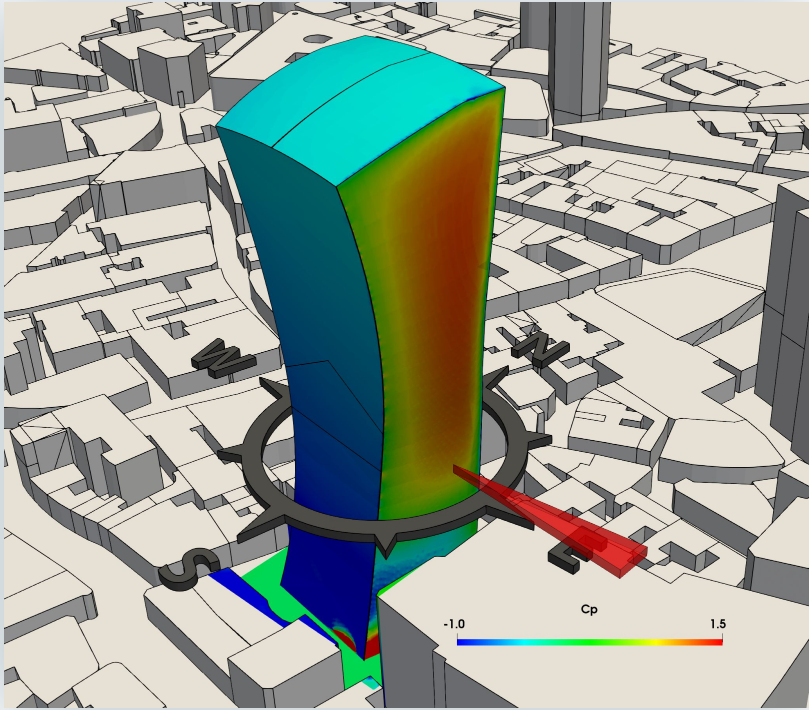
Results at 0° for SW Direction





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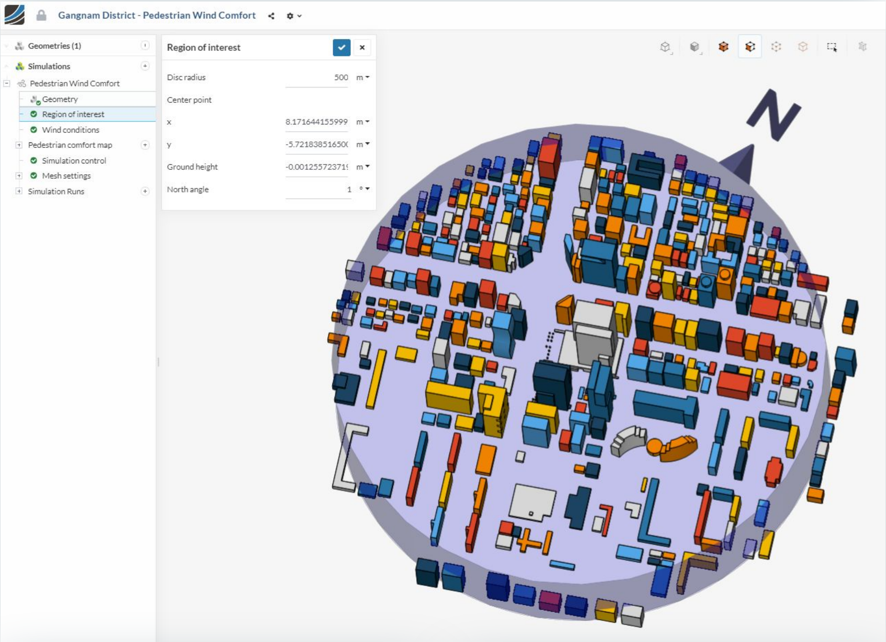
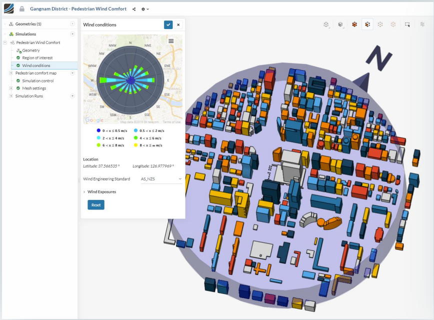
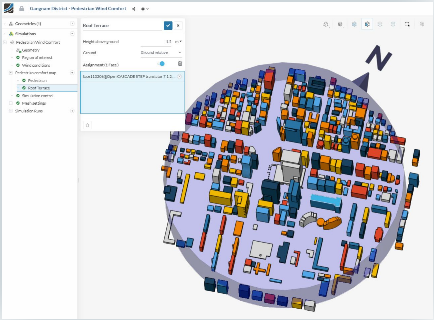
Simulating Thermal Comfort and the Outdoor Environment

Building Aerodynamics & Wind Comfort







Building Aerodynamics

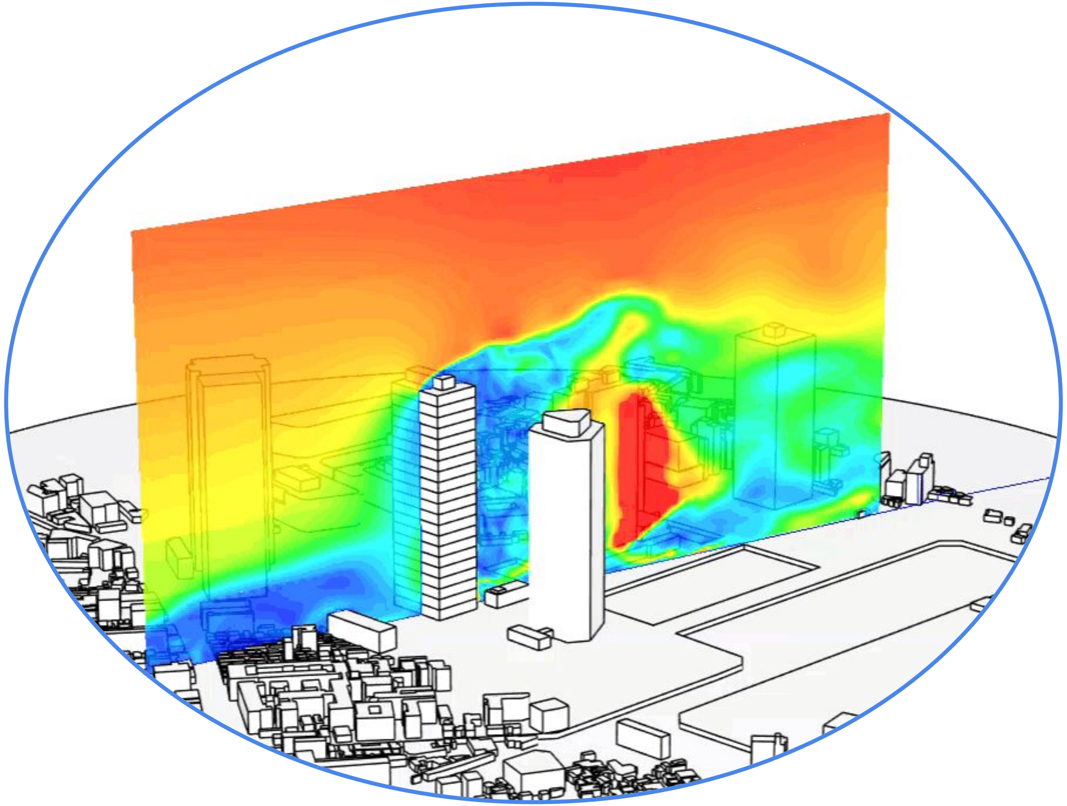
2 Minute Set-Up

It's that simple.

1. Define region
2. Define wind rose
3. Define pedestrian zones

What are the different wind effects generated by buildings?

3D Slice



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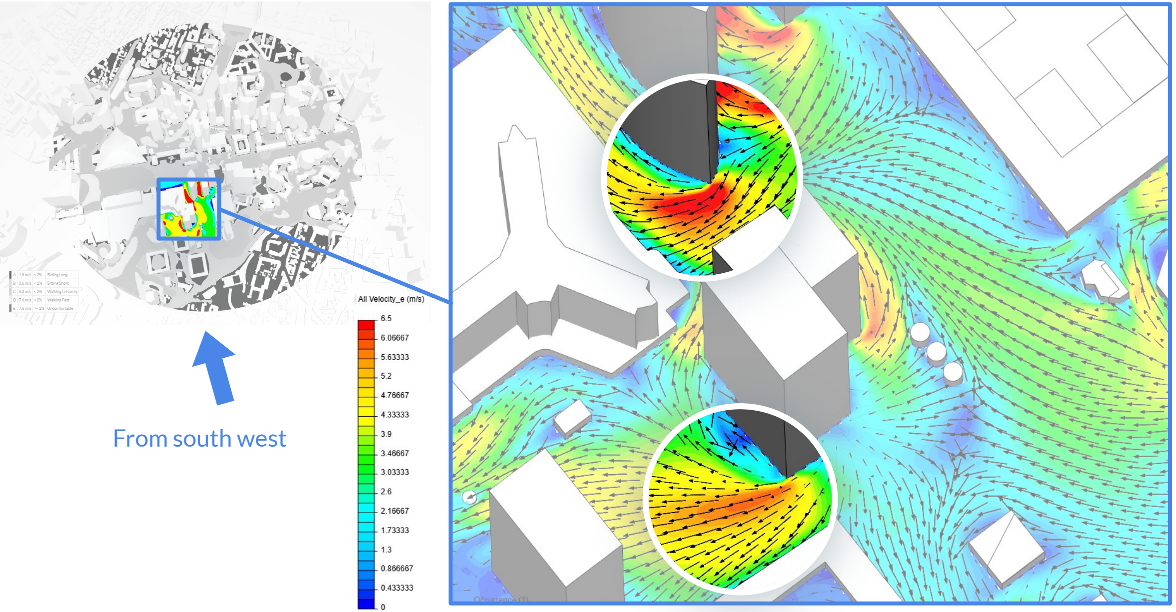
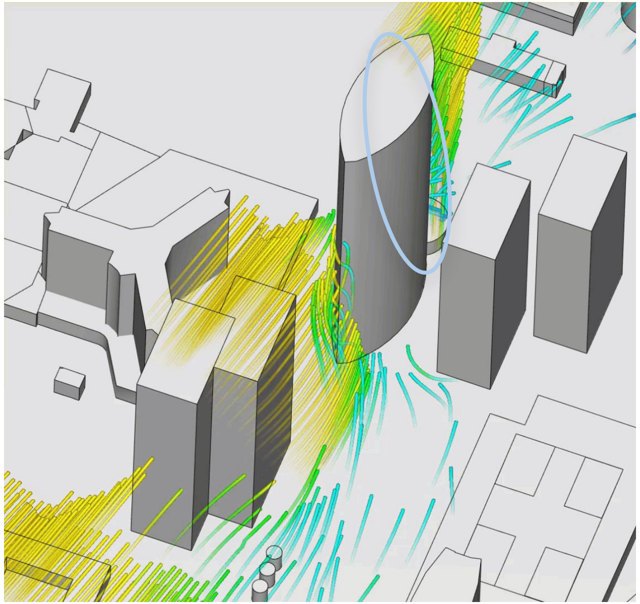
What are the different wind effects generated by buildings?

Corner Acceleration

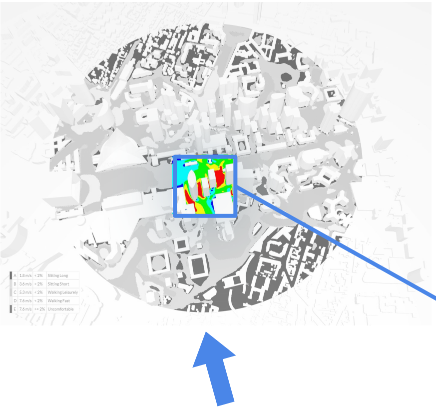


Velocity contour at 1.5 m height

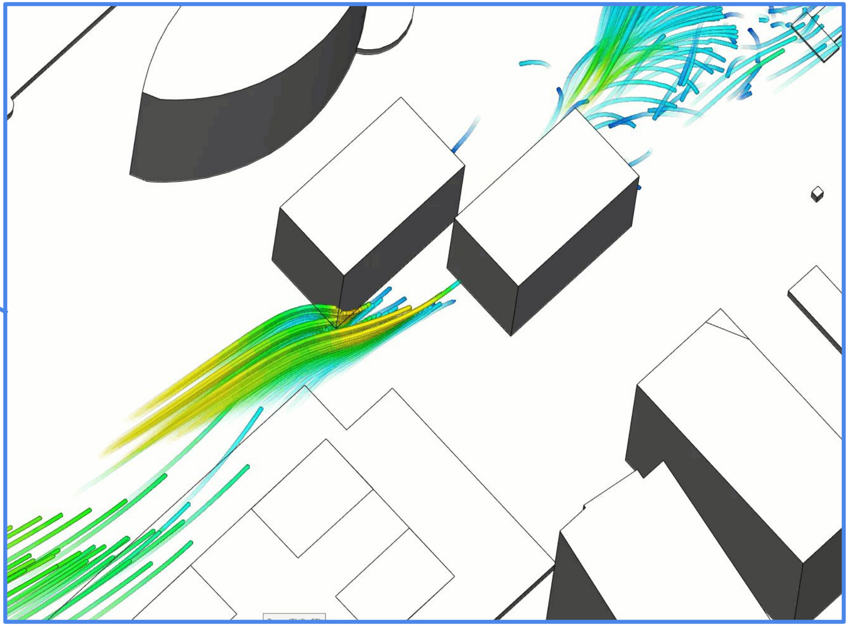


What are the different wind effects generated by buildings?

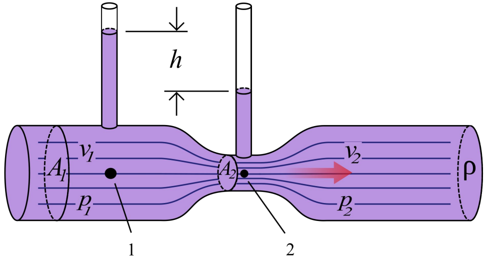
Channeling Effect



From south west



Buildings and other obstructions will force an increase in wind speed through city streets and other unobstructed channels.

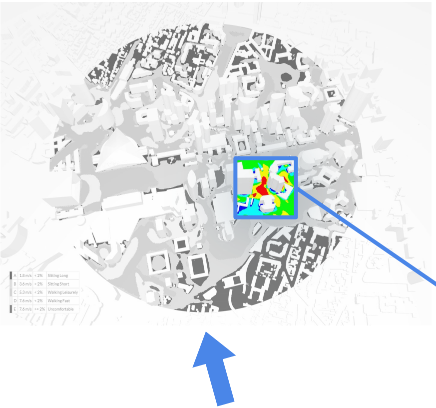


(Source: https://i.stack.imgur.com/gTqm4.png)

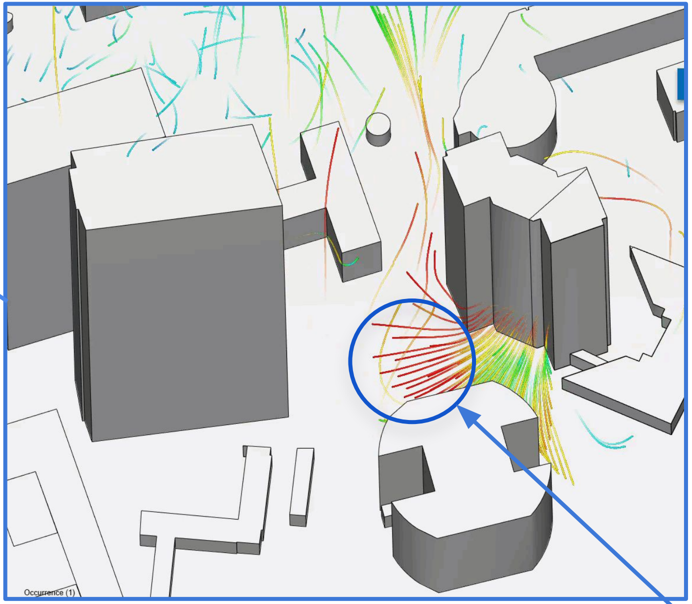
Velocity must increase as it passes through a constriction.

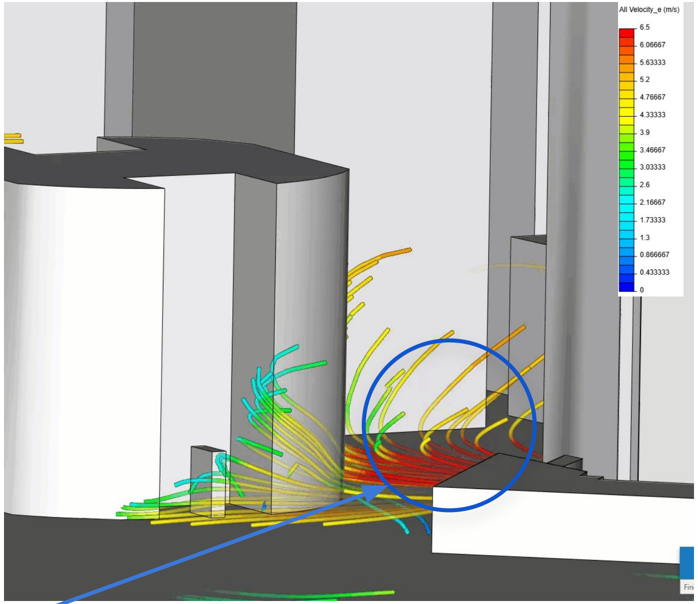
What are the different wind effects generated by buildings?

Downwash Effect



From south west





Wind velocities at 6.5 m/s at low altitude

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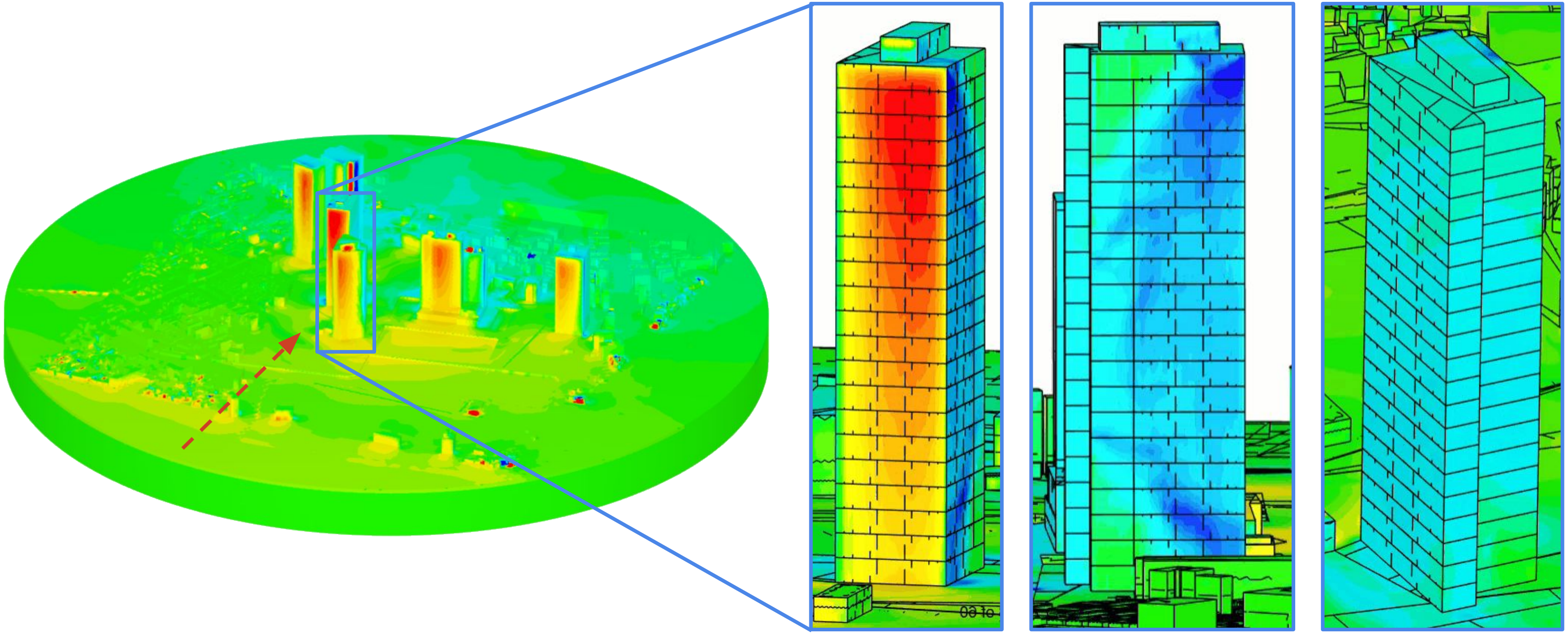
What are the different wind effects generated by buildings?

Wind Loading and Facade Pressures



Front side

Left side

Back and Right side view

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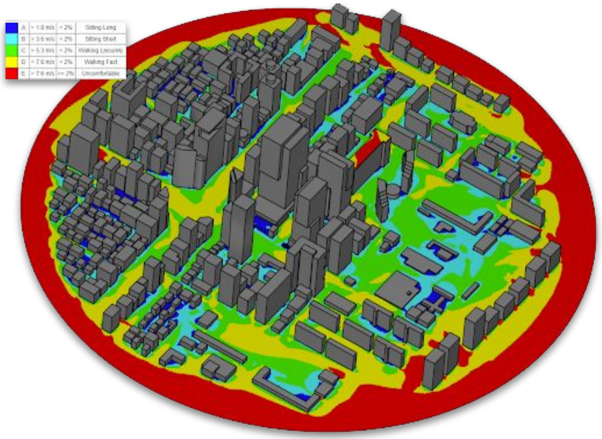
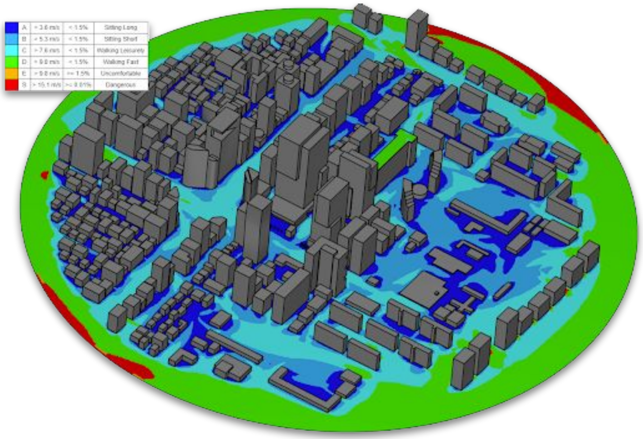
Comfort Criteria Results

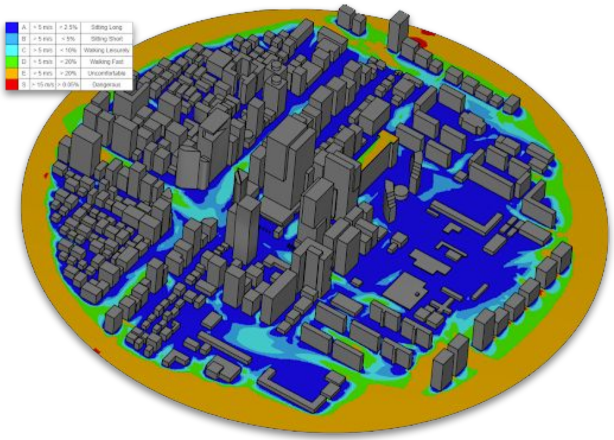
Lawson



Davenport

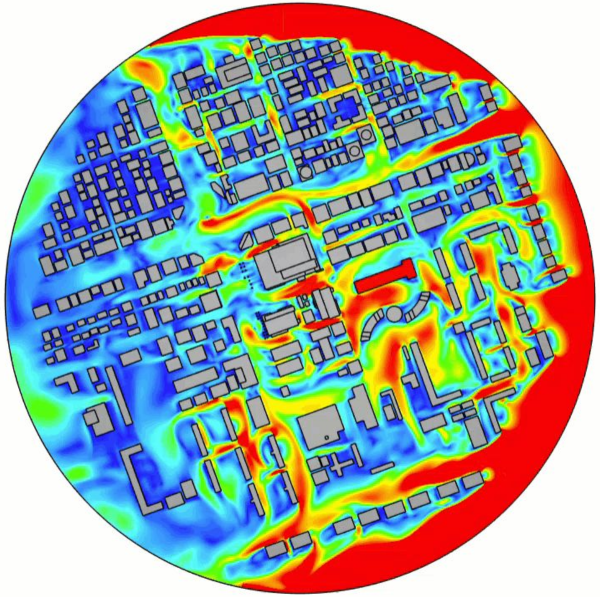


NEN 8100

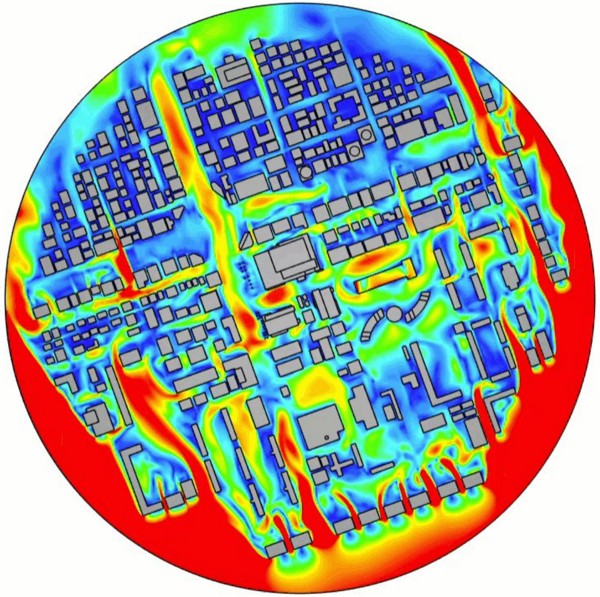


Transient Results

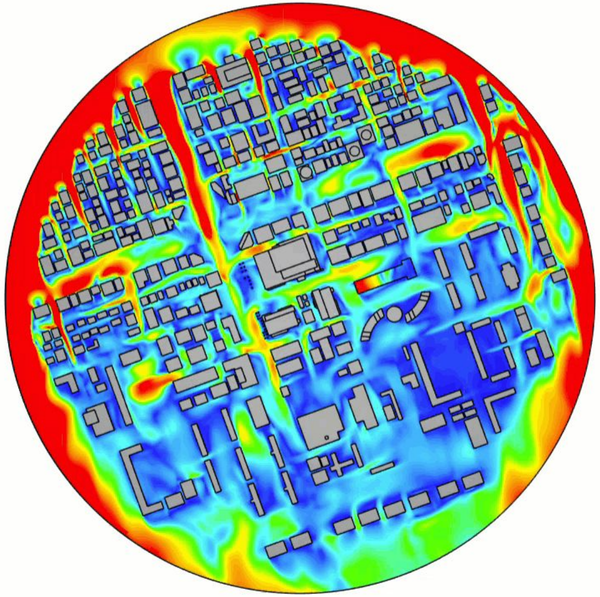
0 deg



90 deg



270 deg



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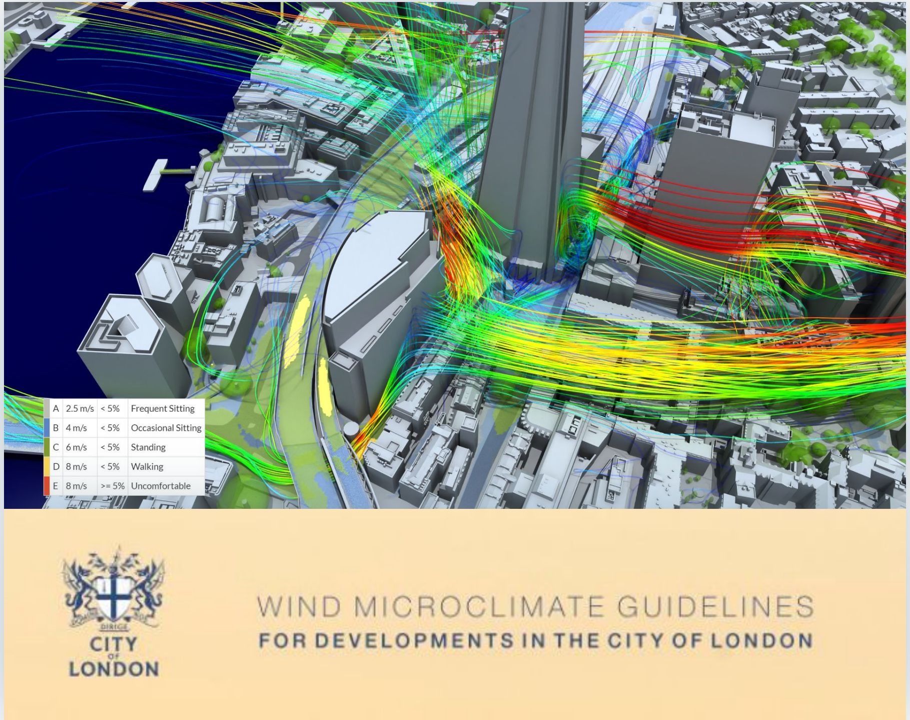
City of London Wind Microclimate Modelling Tool

- Complies with all the required input parameters of the new standard and the modelling outputs
- Up to 36 wind directions in parallel
- Including all the necessary climate and wind profile parameters



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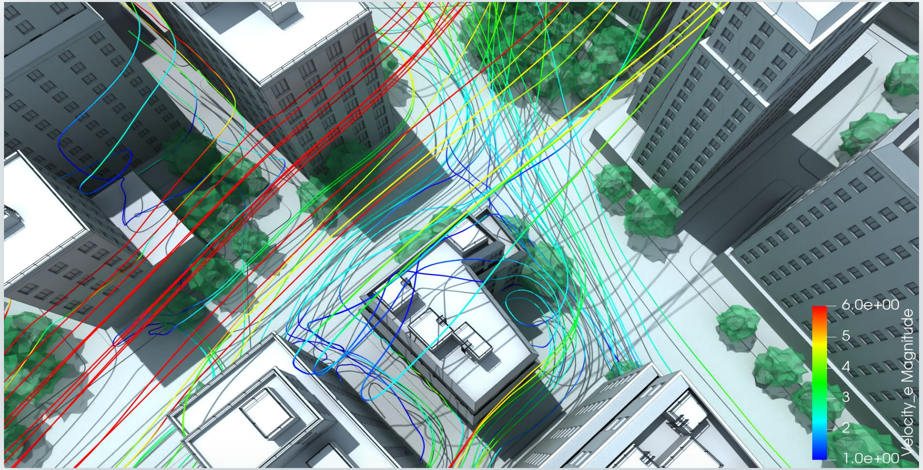

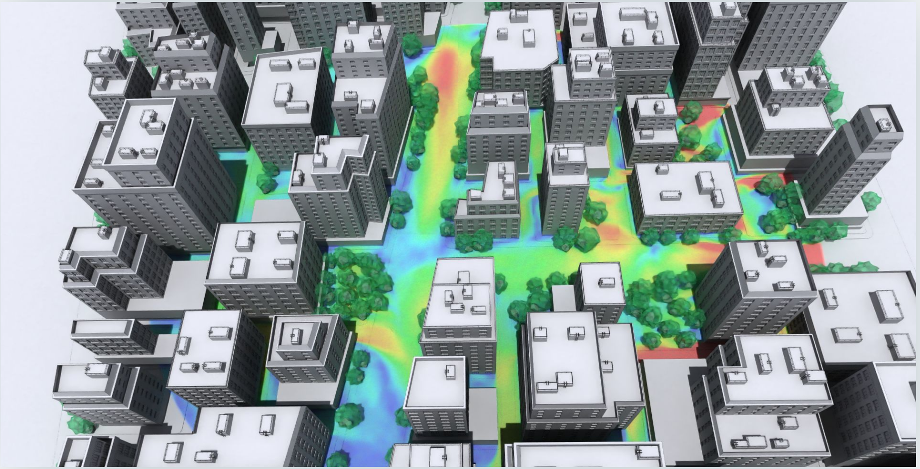

Model Trees Using the Porous Media Feature

- Pedestrian comfort due to:
    - Trees
    - Landscaping
    - wind screens
    - Canopies
    - Streetscape and street furniture
    - Cyclists
- Choose from various common tree species
- Urban greening strategies

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Q&A

Now, ask us anything.
Or email me at nkhan@simscale.com