Lecture

FLAIR

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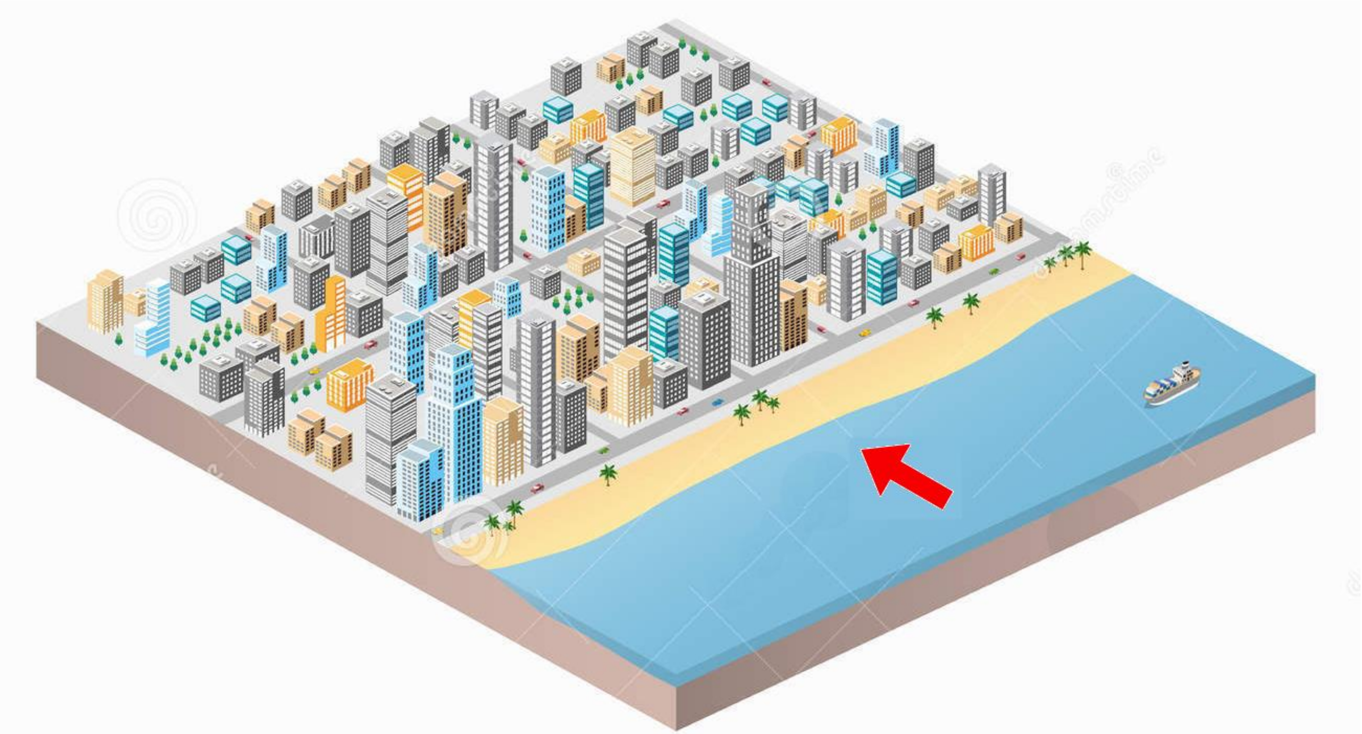
FLAIR is a variant of PHOENICS specifically intended for Building Services and Environmental applications.



FLAIR - Applications

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Internal Analyses

- Ventilation in atria, offices, theatres, conference centres, clean rooms - air velocities and temperatures
- Natural ventilation in apartments
- Fires - safety issues - smoke, visibility distance
- Clean rooms
- Ventilation efficiency - air changes per hour, mean age of air, stagnant regions
- Comfort indices - effect on comfort of temperature, airflow, humidity, radiation
- Ventilation to disperse potential gas leaks - safety

FLAIR - Applications

Transport

- Air pollution from buses in transport interchanges
- Wind screens in bus stations, railway stations
- Ventilation in car parking garages
- Ventilation in railway carriages
- Pressure effects from passing trains
- Fires in underground railway stations
- Fires in road tunnels

FLAIR - Applications

External Analyses

- Wind around buildings
- Solar warming of the built environment – Urban Heat Island effects
- Street canyons
- Pedestrian comfort in windy situations (e.g. Lawson criteria)
- Chillers on roofs – re-entrainment of warm air
- Pollutant releases from chimneys, stacks
- LPG releases from storage facilities
- Pollutant releases in rivers, estuaries

FLAIR – Differences from “Core” PHOENICS

FLAIR does not include some of the more complex features of PHOENICS, e.g.

- Combustion and chemical reaction
- Two-phase flows
- Free-surface flows

FLAIR – Differences from "Core" PHOENICS

FLAIR does include:

- CAD import capabilities
- All the turbulence models of PHOENICS
- The radiation models
- The numerical features (solvers, difference schemes)

The "Look and Feel" of FLAIR is similar to "Core" PHOENICS

FLAIR – Differences from “Core” PHOENICS

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FLAIR <u>also includes</u> specific features relating to buildings or the environment, e.g.

- Objects for diffusers and jet-fans
- Features for modelling fires
- Objects to generate global flow parameters
- Comfort indices – huge selection
- Easy specification of pollutants and aerosols
- Fan operating point and system curve
- Sprinklers for fires
- Wind and sun
- Wind-driven rain
- Foliage

Overview …

The following panels give an overview of FLAIR's capabilities.

Diffusers

- FLAIR provides objects to represent diffusers in which air enters the domain in various complex ways.

- Round
- Vortex
- 4-way rectangular
- 4-way directional
- Grille/Nozzle
- Displacement

- The following slides show some examples.

Round Diffuser

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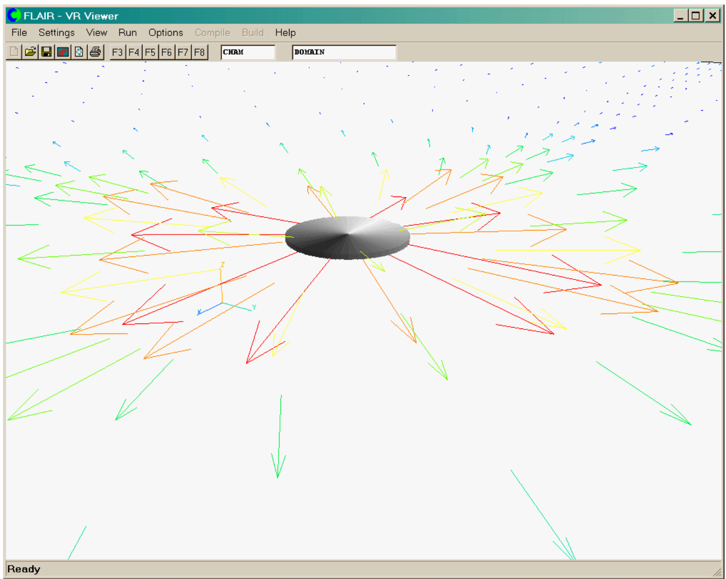

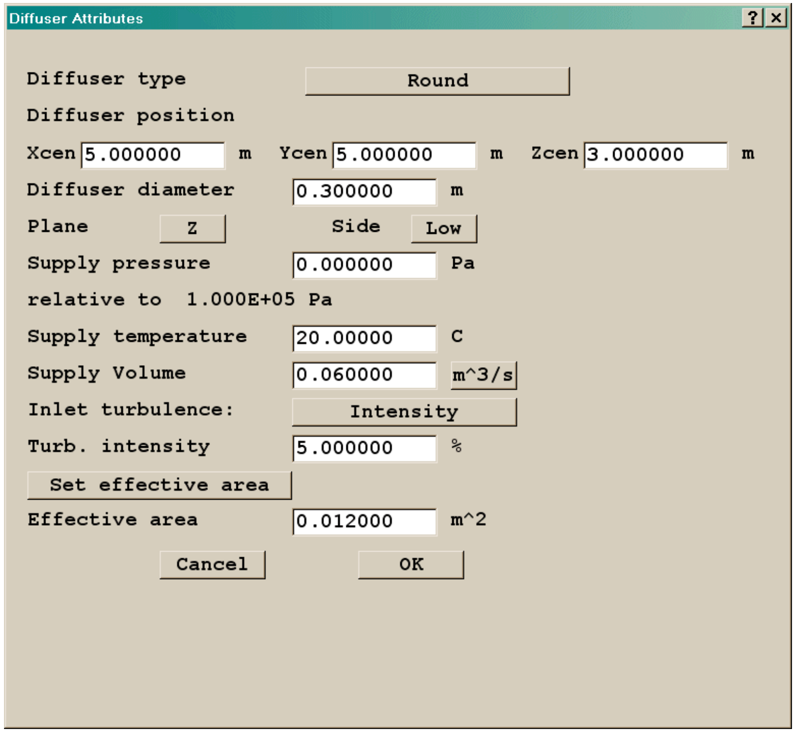

Vortex Diffuser

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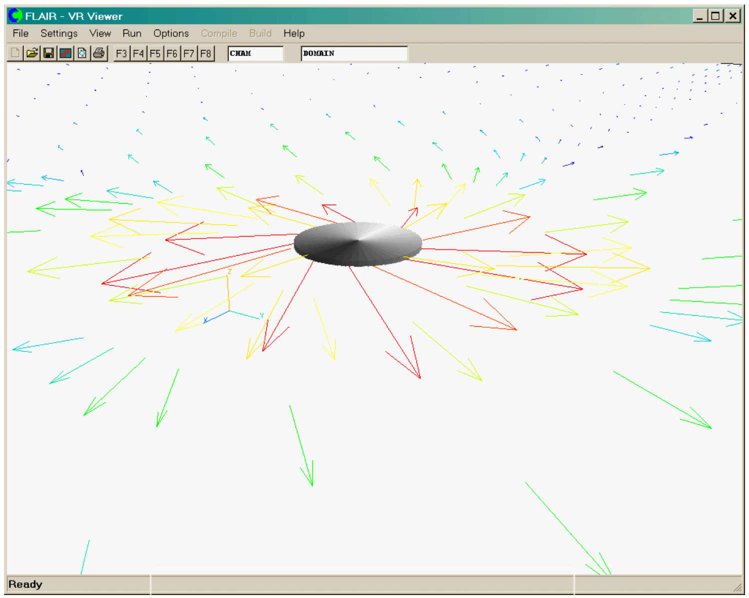

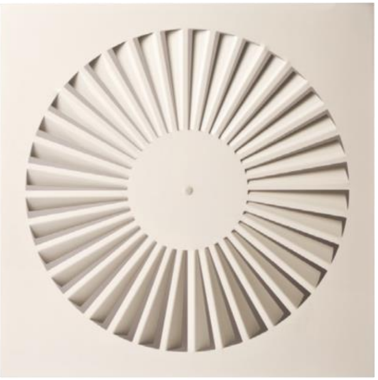

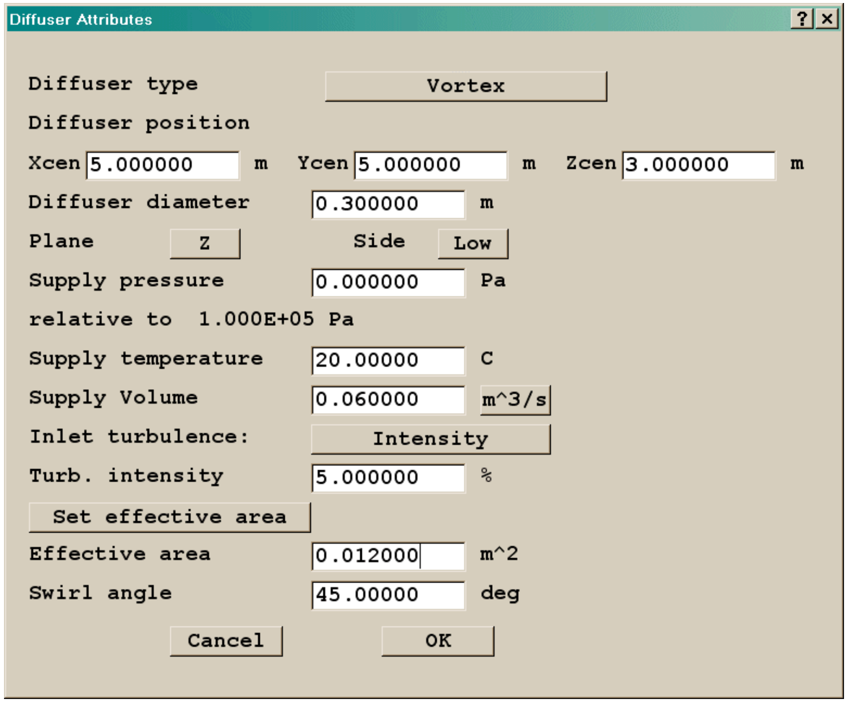

4-way Rectangular Diffuser

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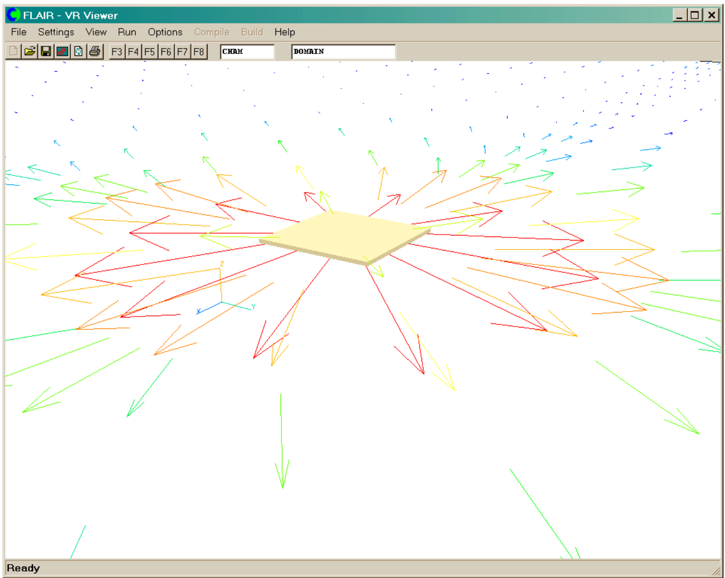

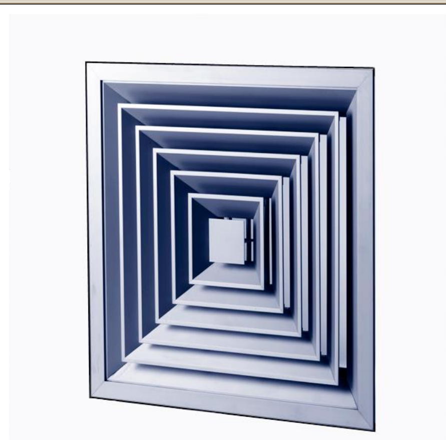

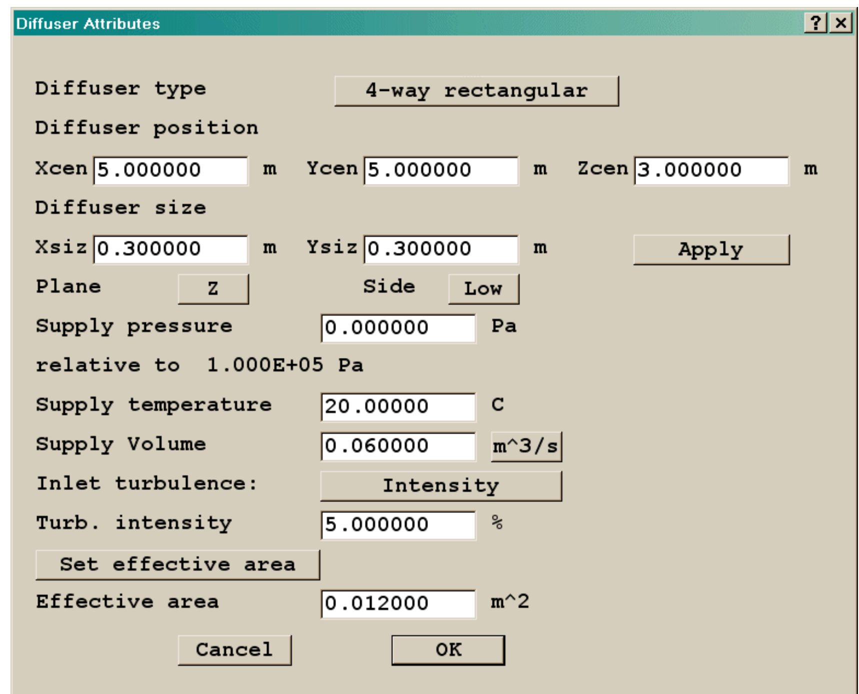

4-way Directional Diffuser

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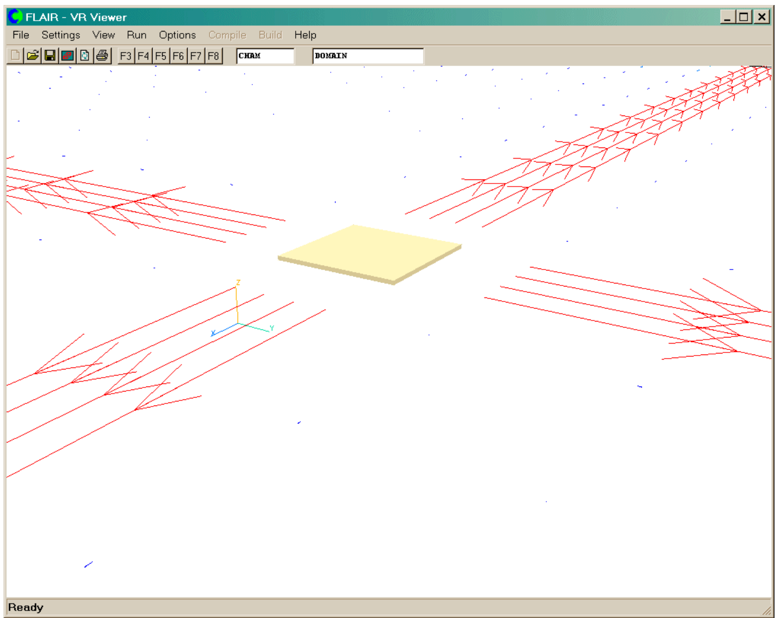

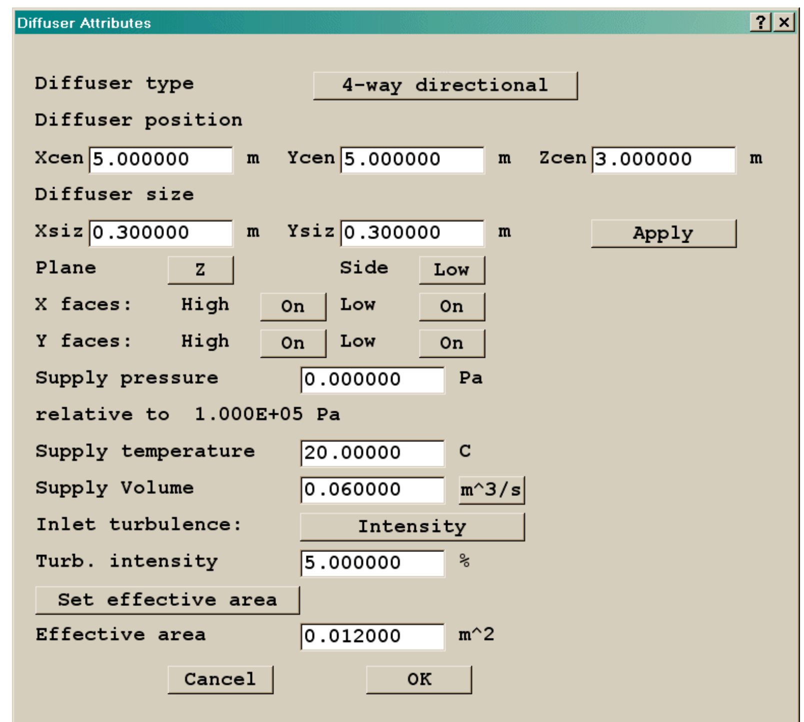

Displacement Diffuser

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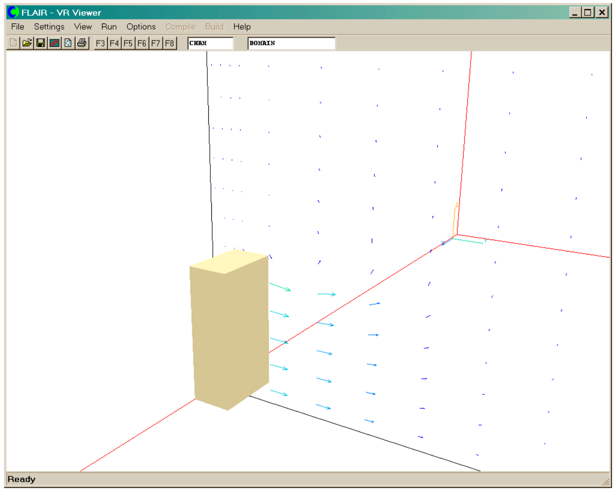

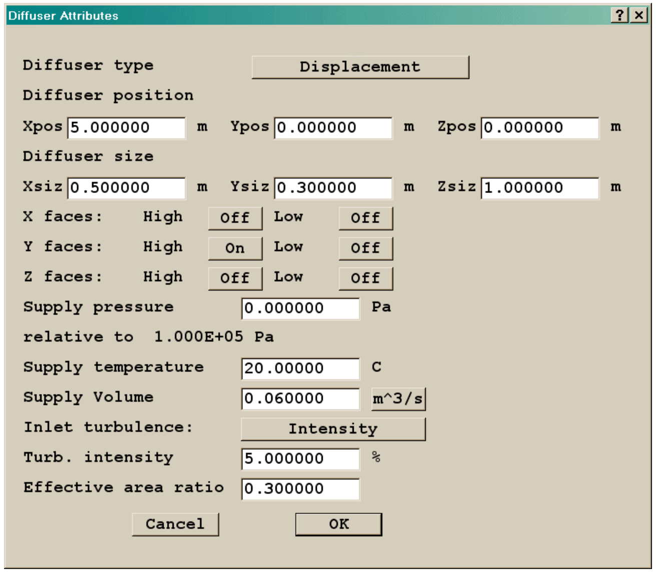

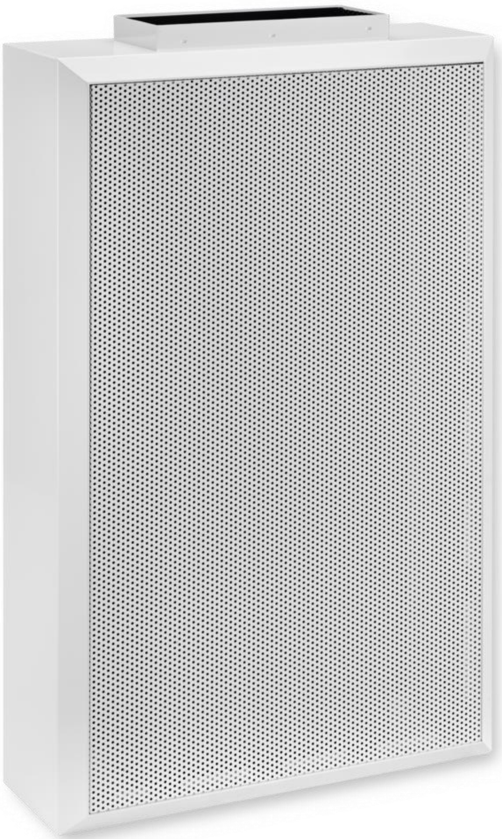

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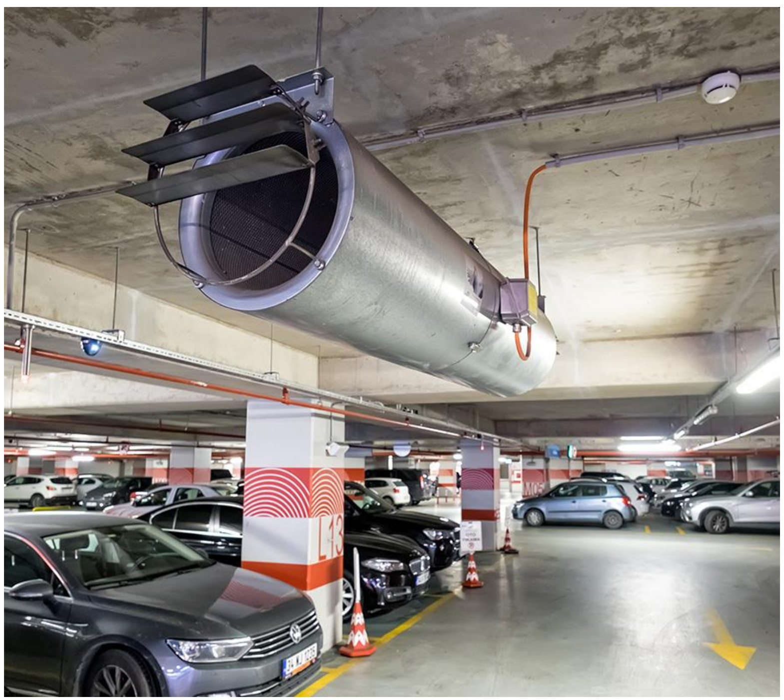
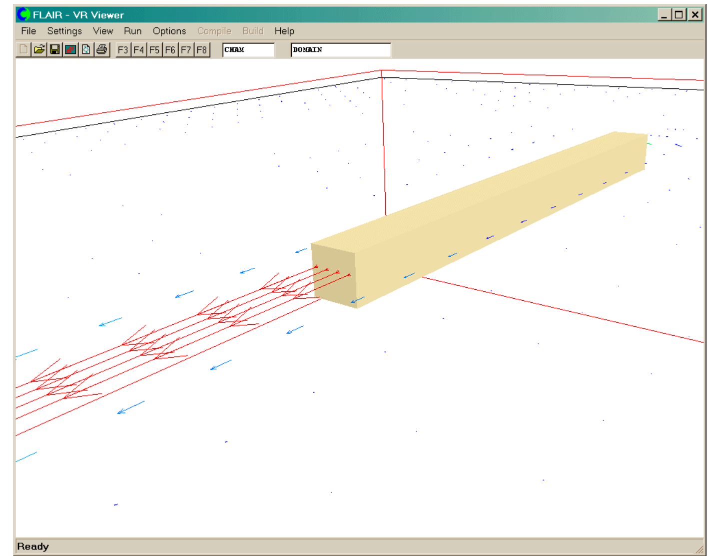
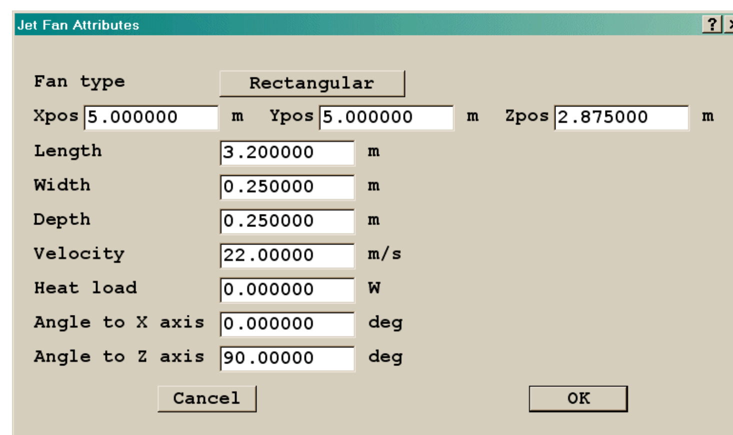
Jet Fan

- Useful for car parking garages and road or railway tunnels







Solve for Pollutants

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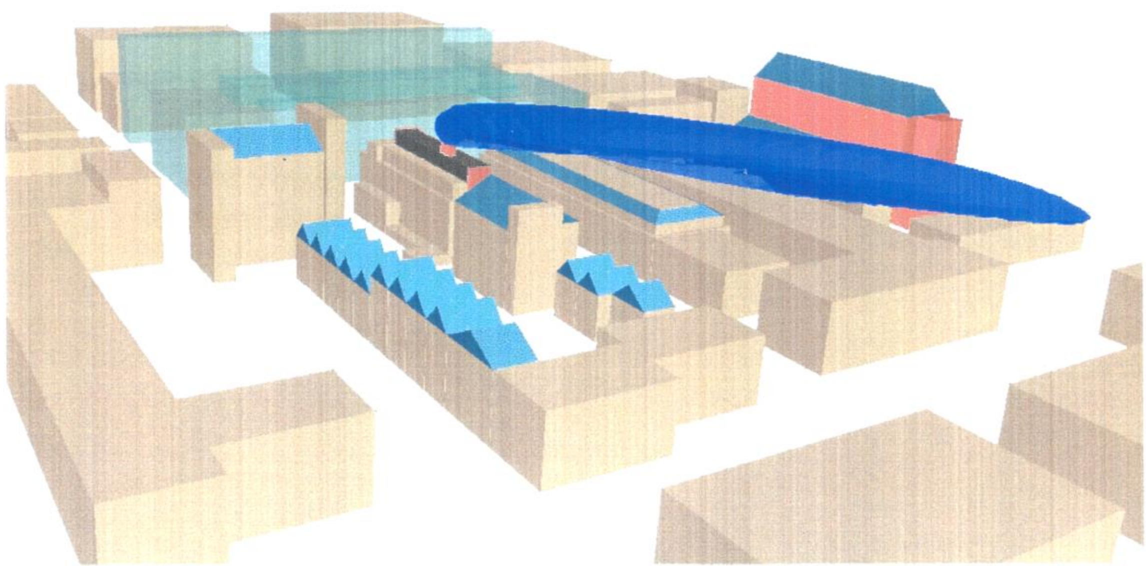
- Easy to set up using Pollutants menu in “Models”

ID	Status	Name	Molecular weight
0	ON	Carrier	28.97007
1	ON	METH	16.04000
2	OFF	C2	28.97007
3	OFF	C3	28.97007
4	OFF	C4	28.97007
5	OFF	C5	28.97007

Include in gas density calculation ON



Solve for Aerosols

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- Easy to set up using Aerosols menu in “Models”
- Includes effects of particle inertia, gravitational settling, Brownian diffusion, turbulent diffusion, turbophoresis

ID	Status	Name	Density	Diameter	Store DEP/VD/TR/VS
1	ON	C6	1400.000	1.000E-5	☑ ☑ ☑ ☑
2	OFF	C7	1000.000	1.000E-5	
3	OFF	C8	1000.000	1.000E-5	
4	OFF	C9	1000.000	1.000E-5	
5	OFF	C10	1000.000	1.000E-5	

Gravitational acceleration	X	Y	Z
	-9.810000	0.000000	0.000000

Deposition model: Gravity + diffusion (any Y+)

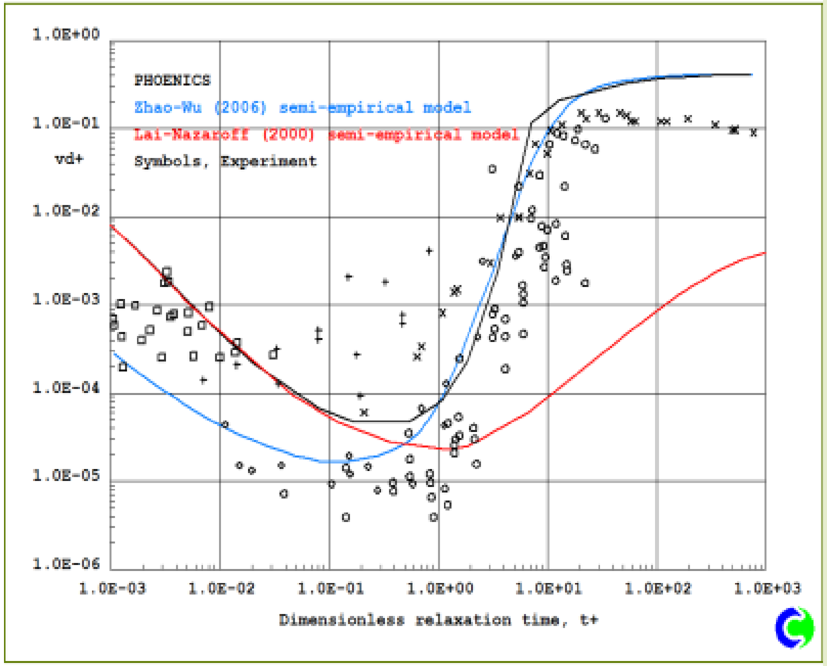

Figure 1: Comparison of measured and predicted particle-deposition rates on smooth vertical duct walls.

Solve for Humidity

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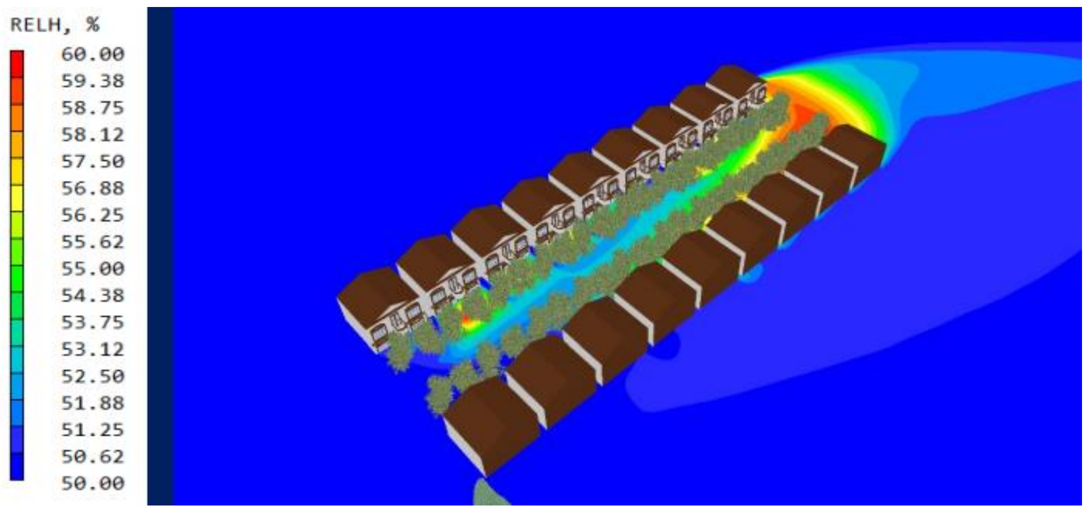
- Switch on solution for mass fraction of water vapour.
- The following can be derived:
  - Relative humidity
  - Humidity ratio
  - Wet bulb temperature
  - Dew point
  - Water vapour partial pressure
  - Water vapour saturation pressure



← Figure shows RH increasing as wind blows past street trees

Person object

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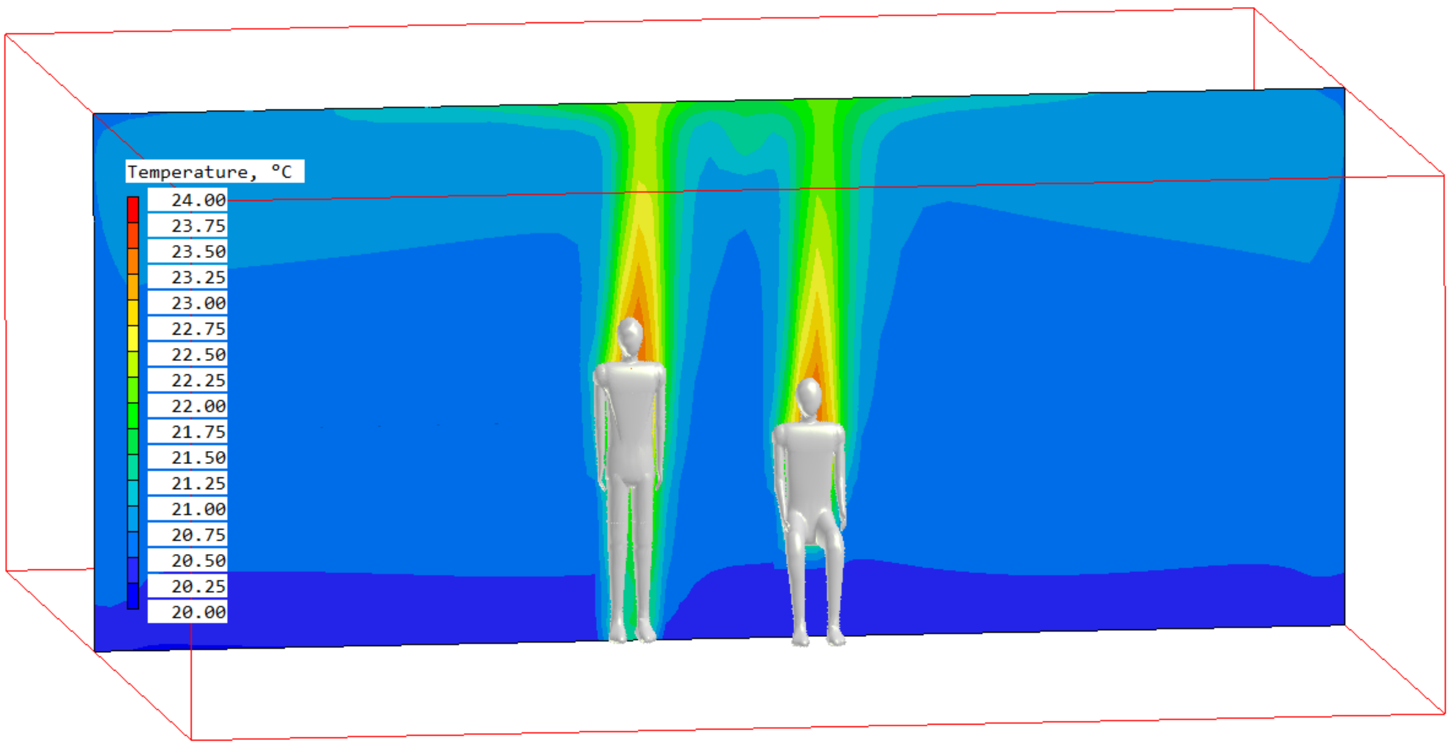
- Person object can be standing or sitting
- Person comprised of “domain material” (i.e. air)
- Specified heat source (watts) for the object
- For a lot of people, may be better to use distributed source



People object

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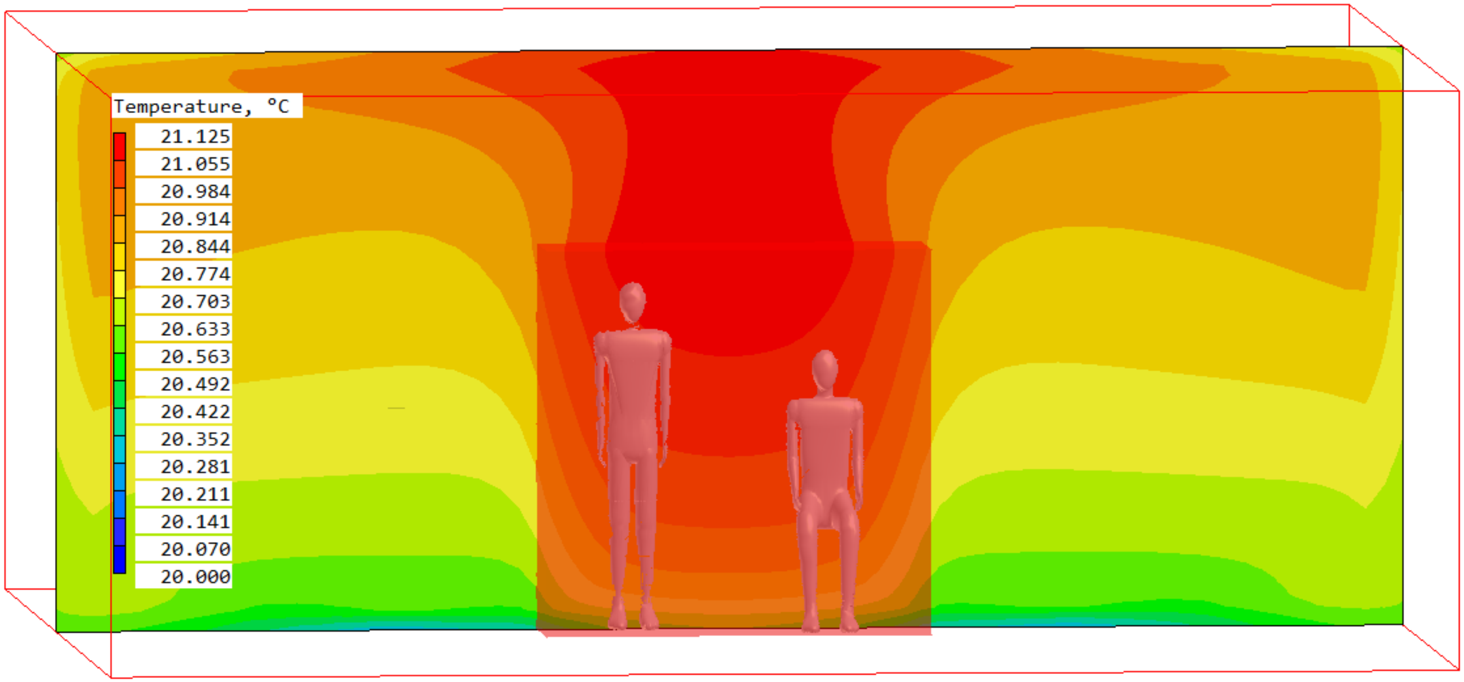
- People object defines a region of space containing a number of people
- Object comprised of “domain material” (i.e. air)
- Specified total heat source (watts) for the object, distributed uniformly



Global Flow Parameters

- The ROOM object enables calculation of the following quantities within any space:

- Total free volume
- Total volumetric inflow rate
- Average, minimum and maximum temperature
- Average velocity at a given height
- Overall residence time (free volume / flow rate)
- Air changes per hour
- Air exchange effectiveness

Fire object

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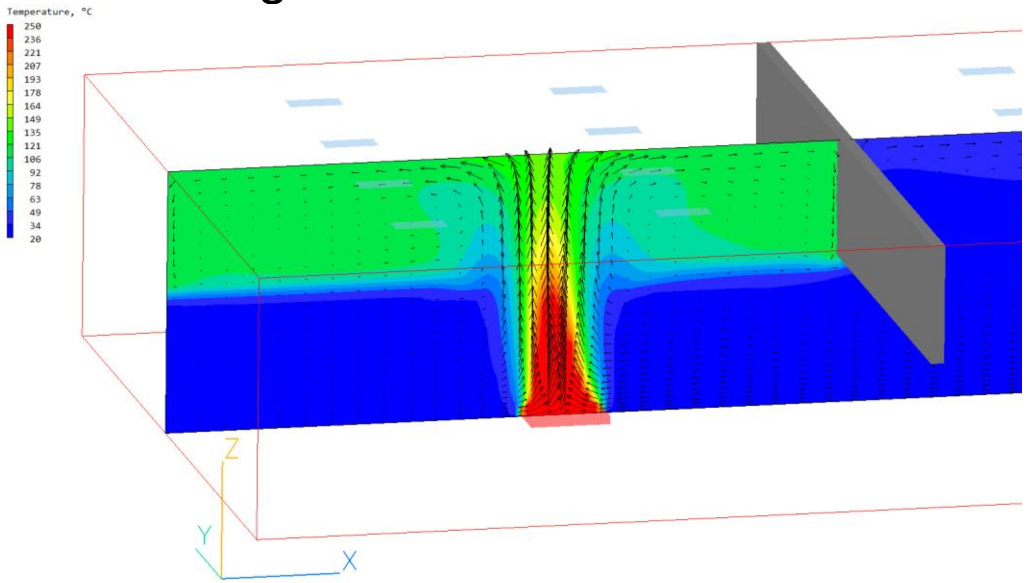
- Fire object represents a fire as a heat source within a specified region (typically a rectangular box)
- Need to specify:
  > heat source as function of time
  > mass source (i.e. mass of gas vaporised from burning materials)
  > scalar source (i.e. source of smoke concentration)
- See “Fire Modelling” lecture for details



Example – Fire in a Tube Train

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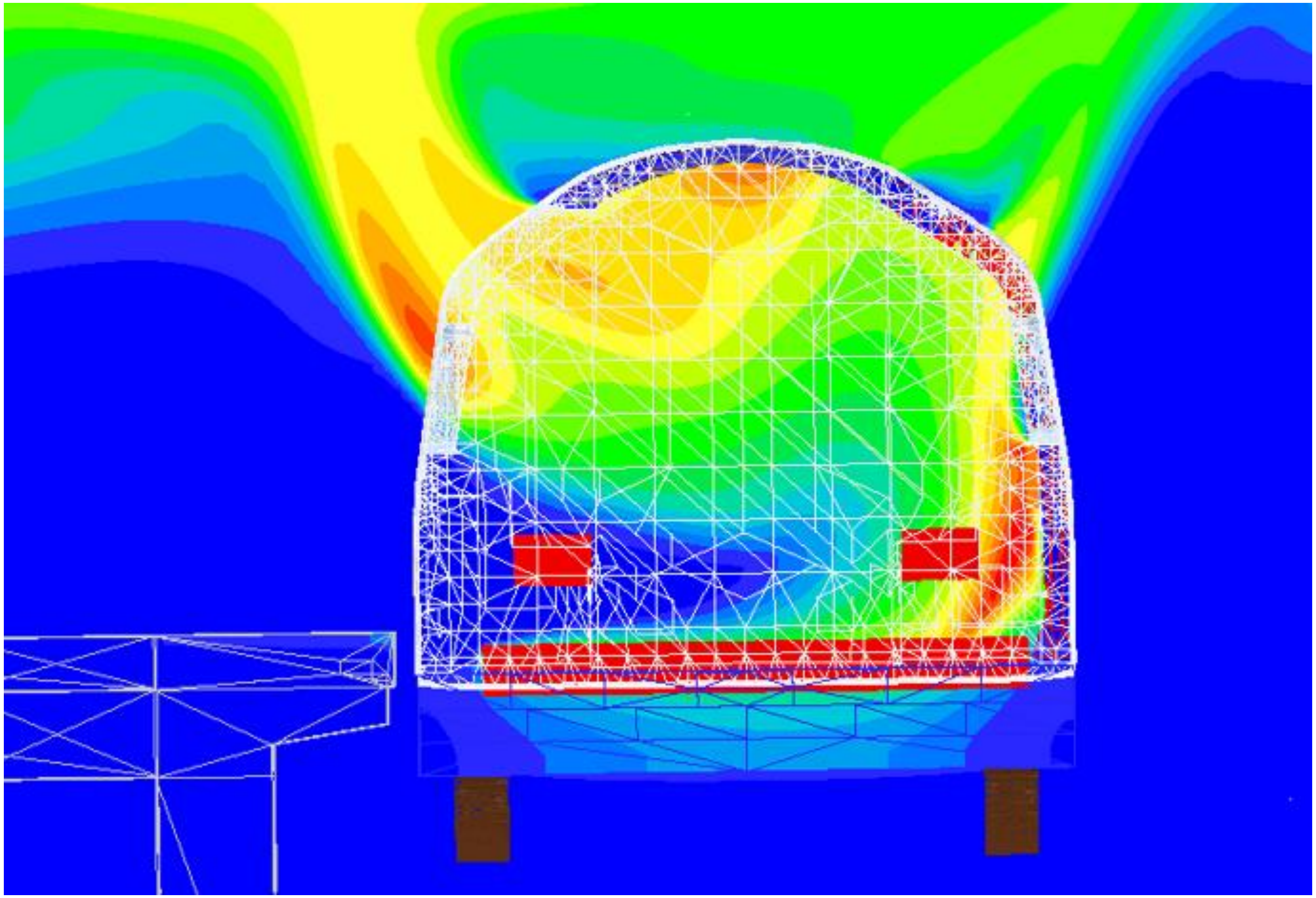

Fire Modelling Capabilities

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FLAIR offers the following features for fire modelling:

- 'International' fire model
- Dutch NEN6098 fire model
- Belgian NBN S 21-208-2/A1 fire model
- Optical Smoke Density
- Sight Length or Visibility Distance
- Light Intensity Reduction

Luggage Fire in an Air Terminal

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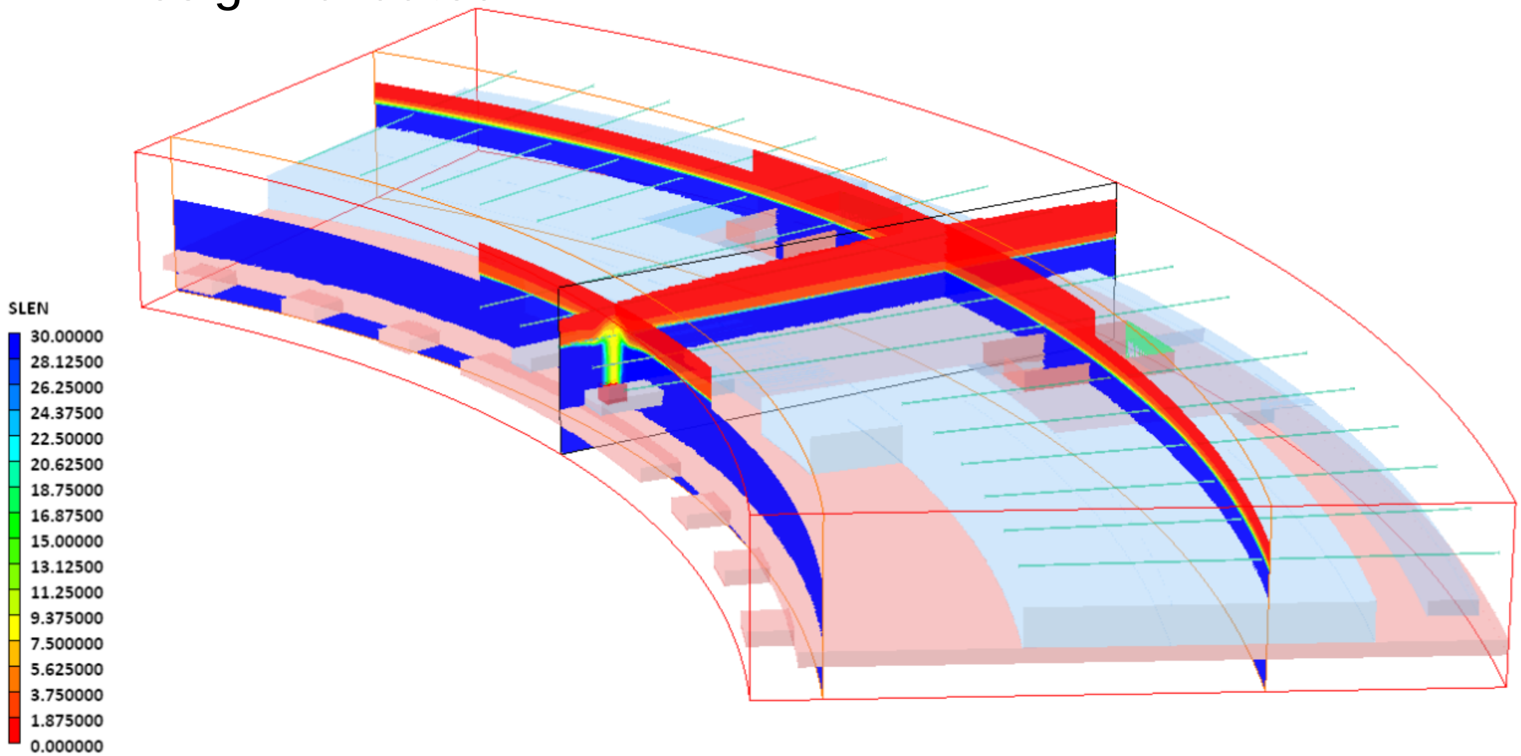
- Plot of visibility length – colours reversed, smoke is red
- High smoke concentrations near ceiling only
- Green lines show the smoke extracts (at bottom of smoke layer)
- Design validated



Modelling Sprinklers

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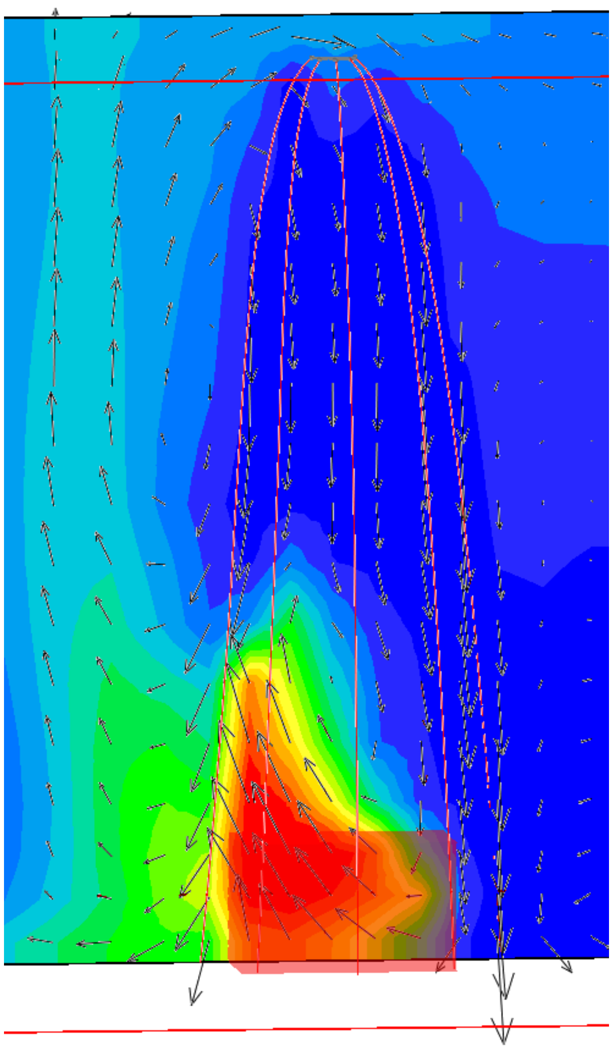
- “Sprayhead” object in FLAIR
- Droplets tracked using Lagrangian GENTRA module
- Can set droplet size, volume flow rate, spray angle, etc
- Droplet evaporation provides a cooling effect



Rain and RainGauge objects

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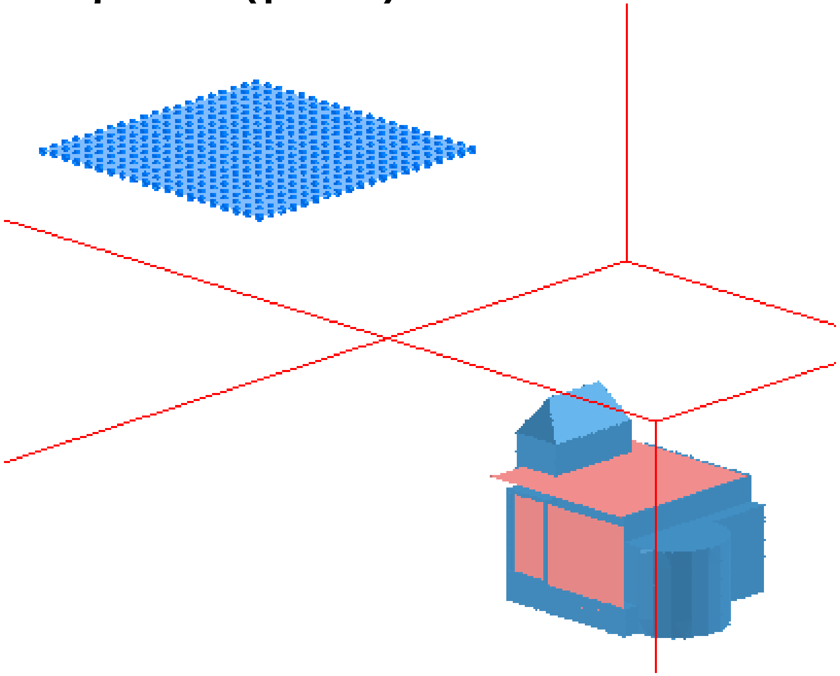
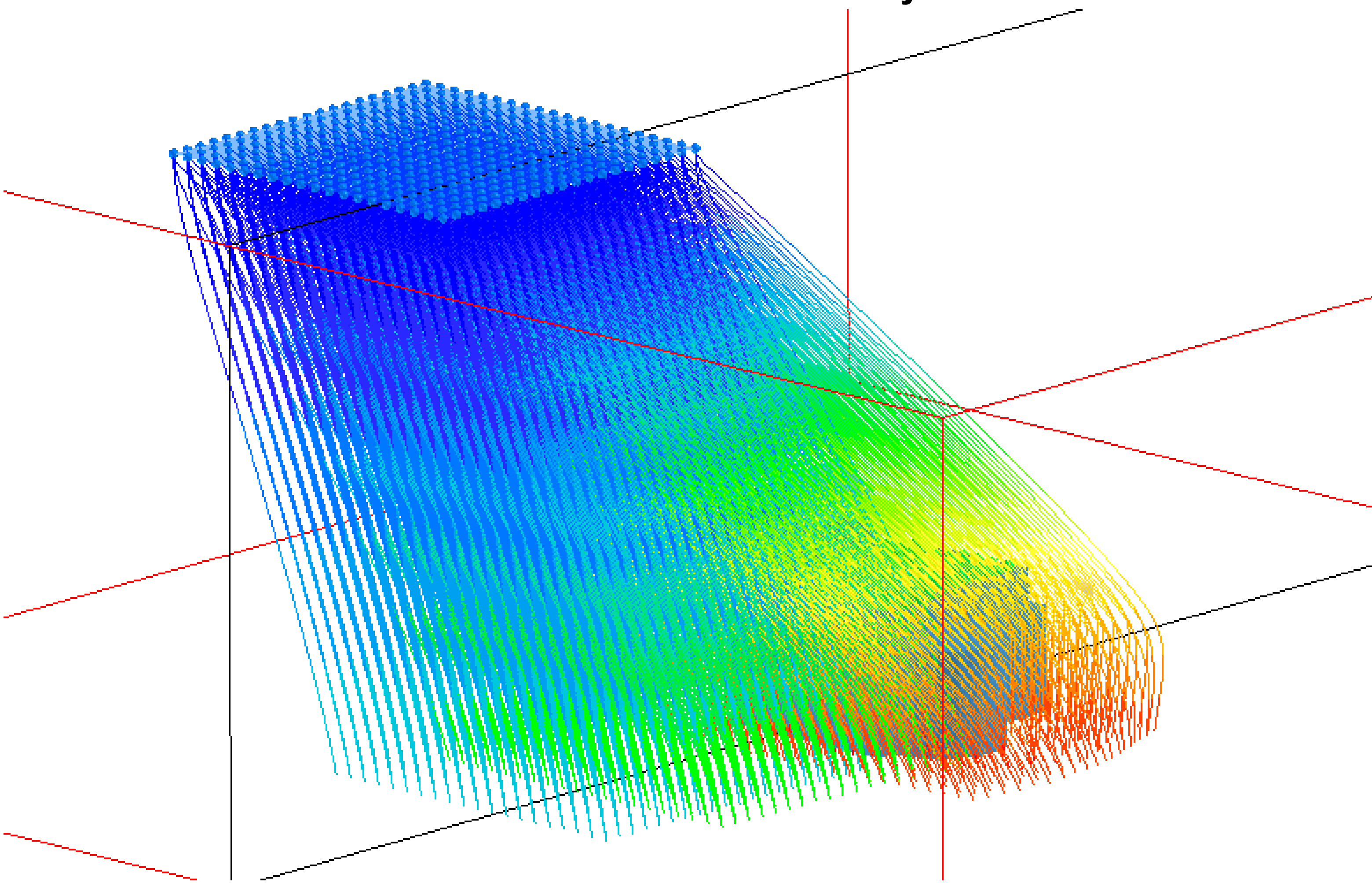
- Wind-driven rain
- Lagrangian approach – solves droplet tracks
- Example - Rain object with 20x20 ports, placed so that tracks go towards building
- RainGauge objects (pink) on wall and roof of building



Rain and RainGauge objects

- All the rain tracks from the Rain object



Rain and RainGauge objects

Lecture

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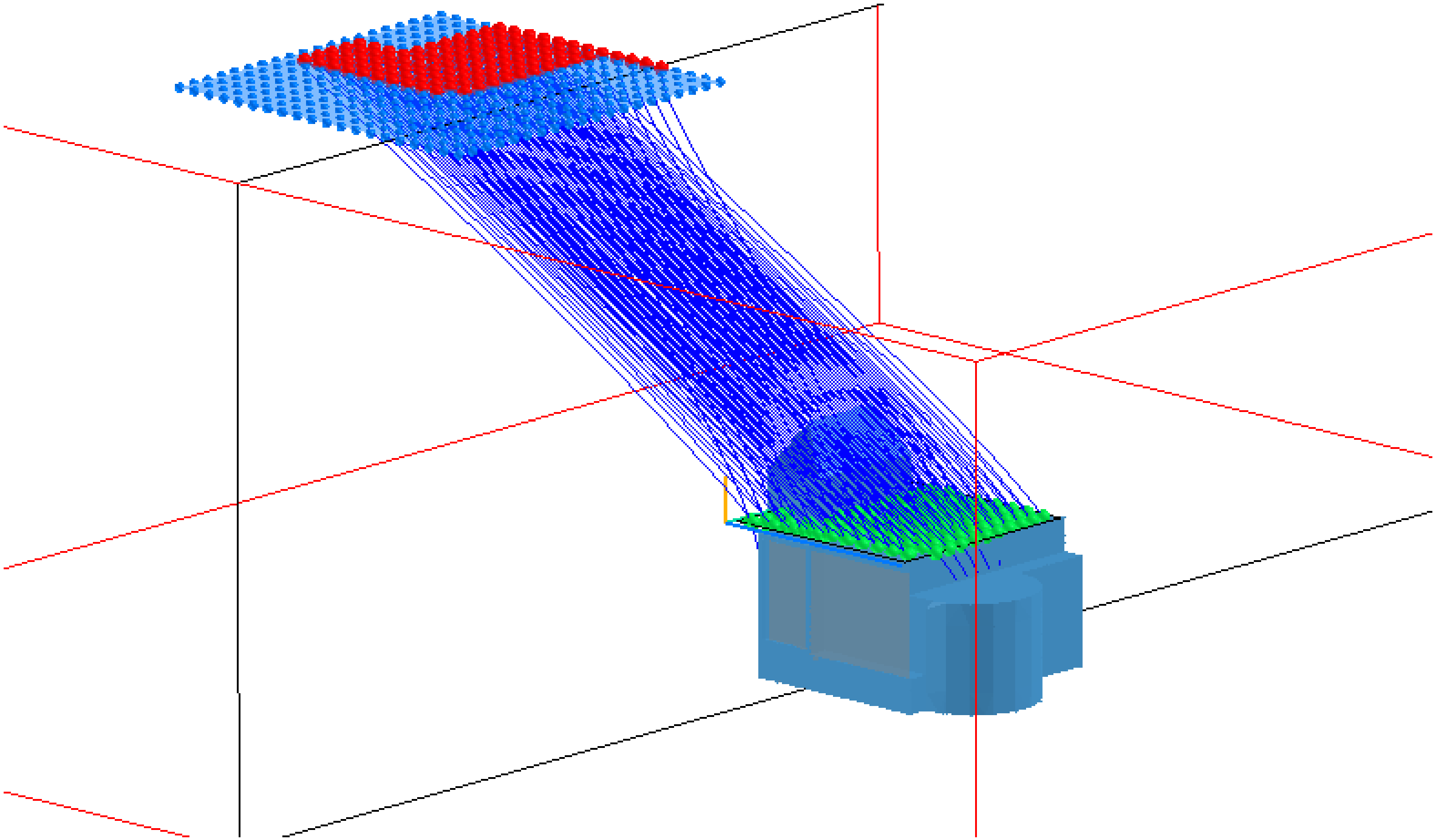
- The rain tracks that impinge on the roof RainGauge
- Green ball at end of each track, red ball at start



Fan Operating Point

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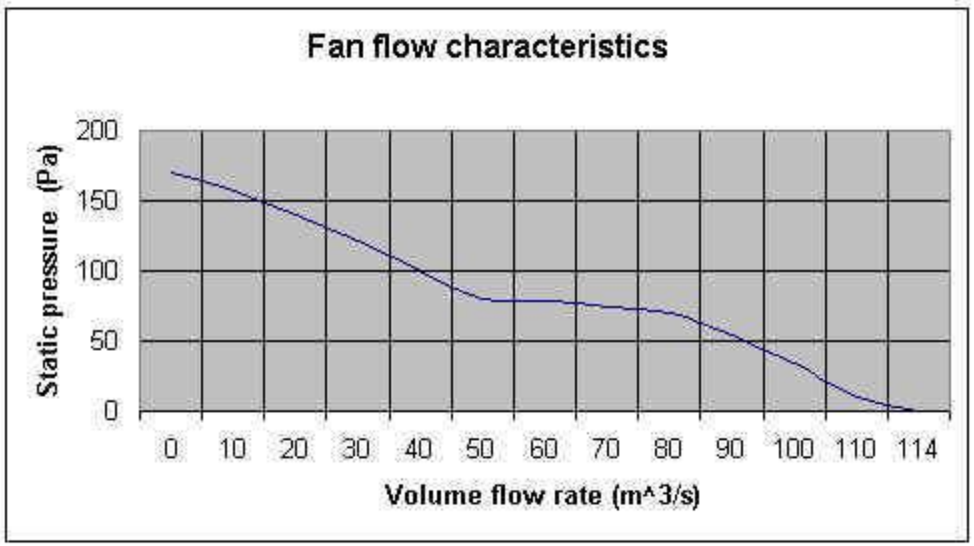
- With this option, the flow rate through a fan is adjusted according to the pressure drop across the fan, using the fan characteristic curve supplied by the manufacturer.



System Curve

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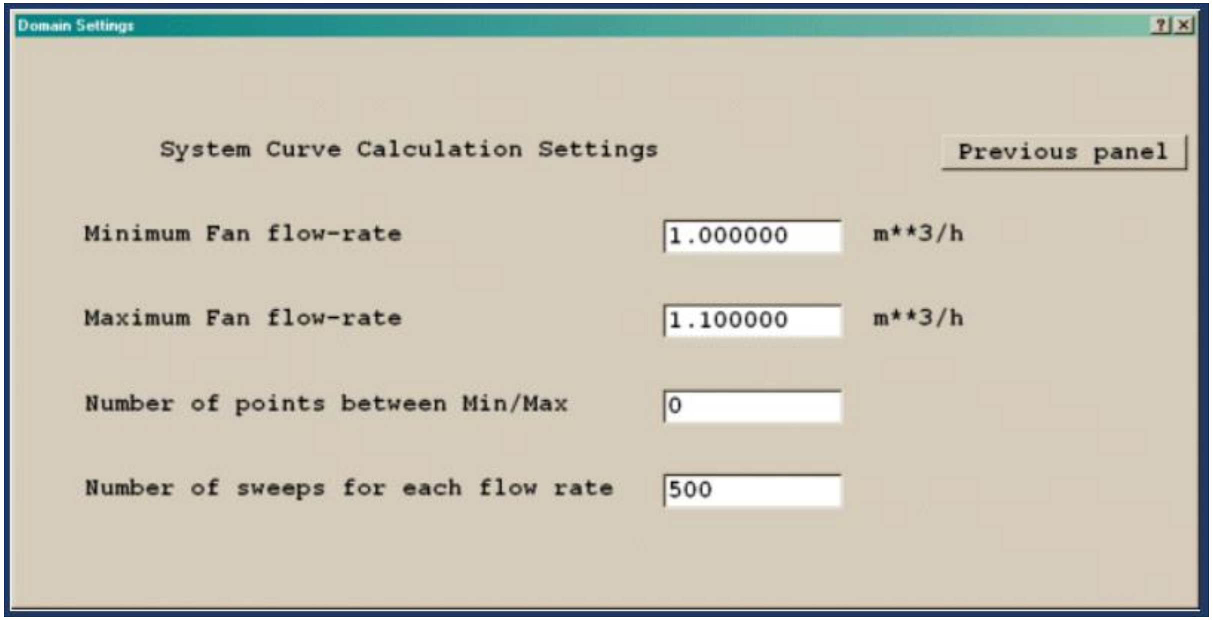
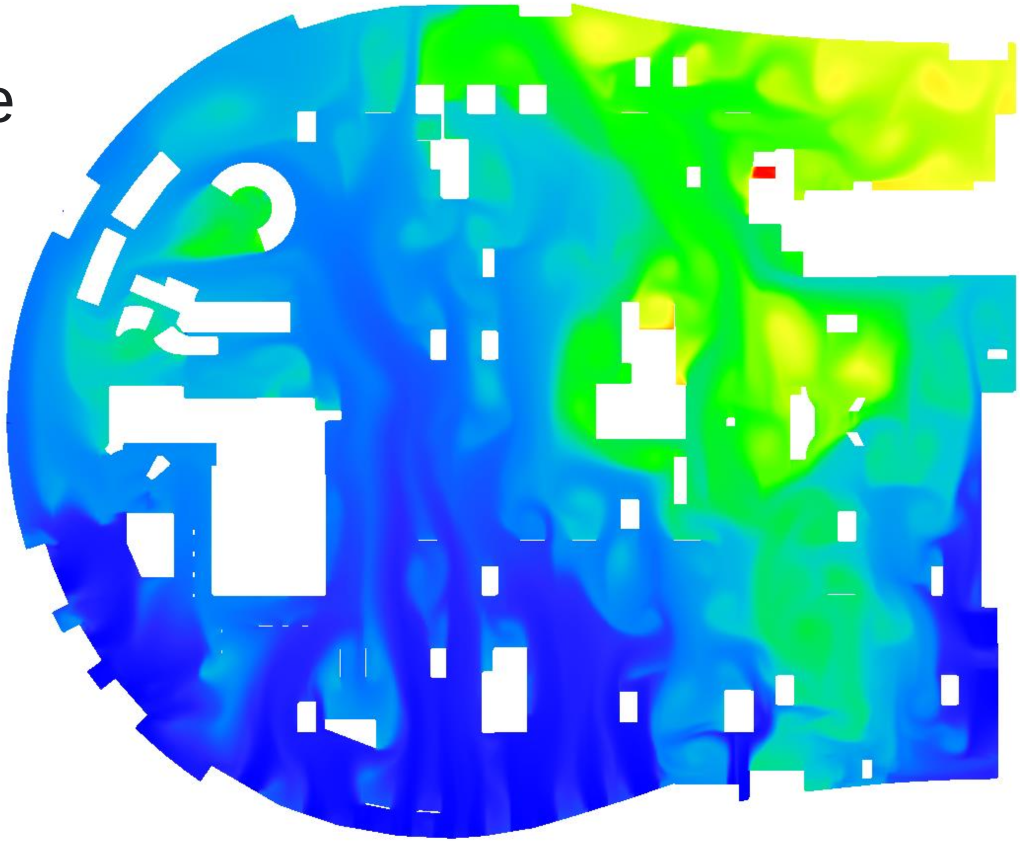
- The System Curve function enables you to perform a number of simulations using different flow rates.
- Predicts pressure drop for each flow rate, allowing you to plot the system curve.



Mean Age of Air

- Mean Age of Air measures mean time since inlet
- High values indicate stagnant poorly-ventilated regions
- e.g. top right here



Comfort Indices

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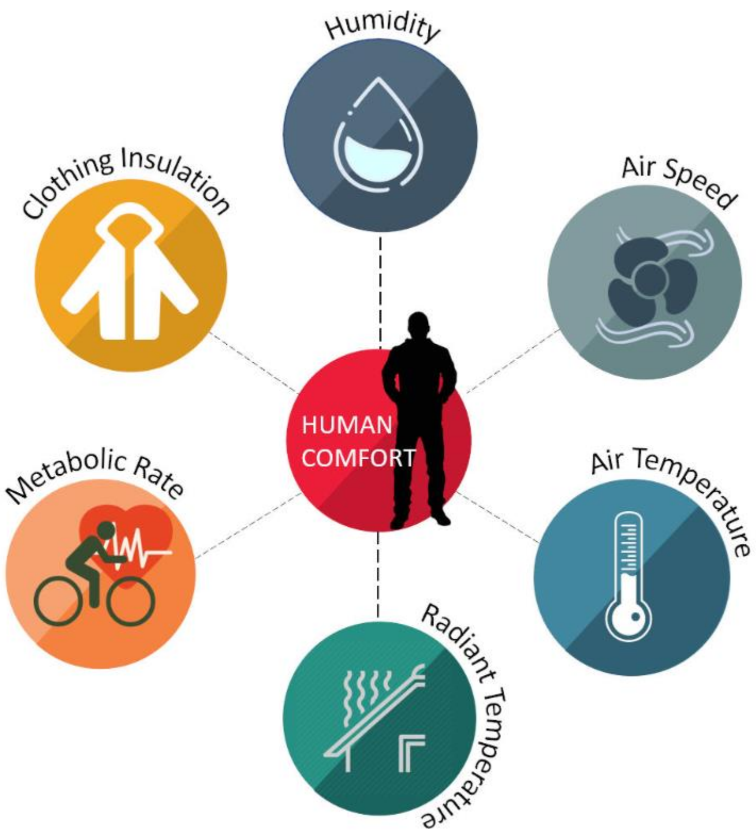
- Describe how the human body experiences its immediate environment
- Typically depends upon the local air velocity and temperature, humidity, thermal radiation.
- Many such indices
- Some for indoors, some for outdoors



Comfort Indices

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- Dry Resultant Temperature
- Apparent Temperature
- Universal Thermal Climate Index (UTCI)
- Physiologically Equivalent Temperature (PET)
- Thermal Sensation Index (TSIB)
- Predicted Mean Vote (PMV)
- Predicted Percentage Dissatisfied (PPD)
- Draught Rating
- Predicted Productivity Loss
- Wet Bulb Globe Temperature

- Pedestrian wind comfort is discussed below

Wind

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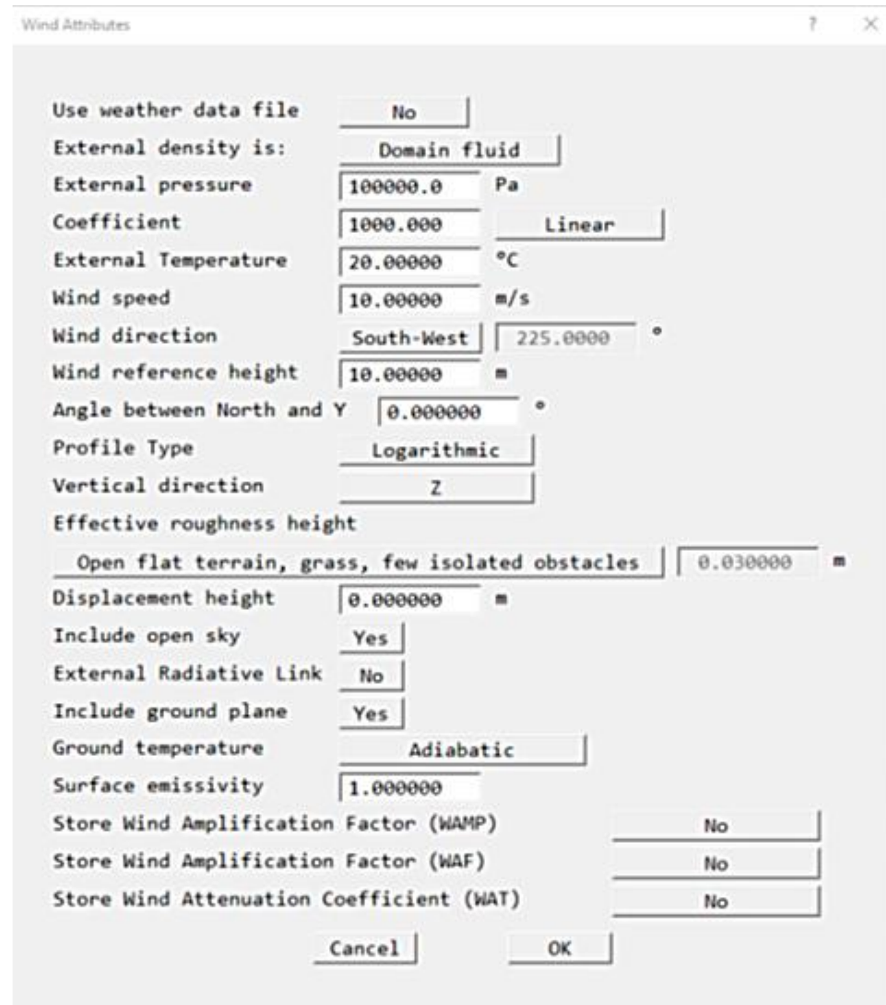
- To model wind, use the WIND object.
- Use it to specify:
- Velocity profile type (power law or log law)
- Velocity at reference height
- Direction
- Roughness height of ground
- etc…



Typical Wind Case

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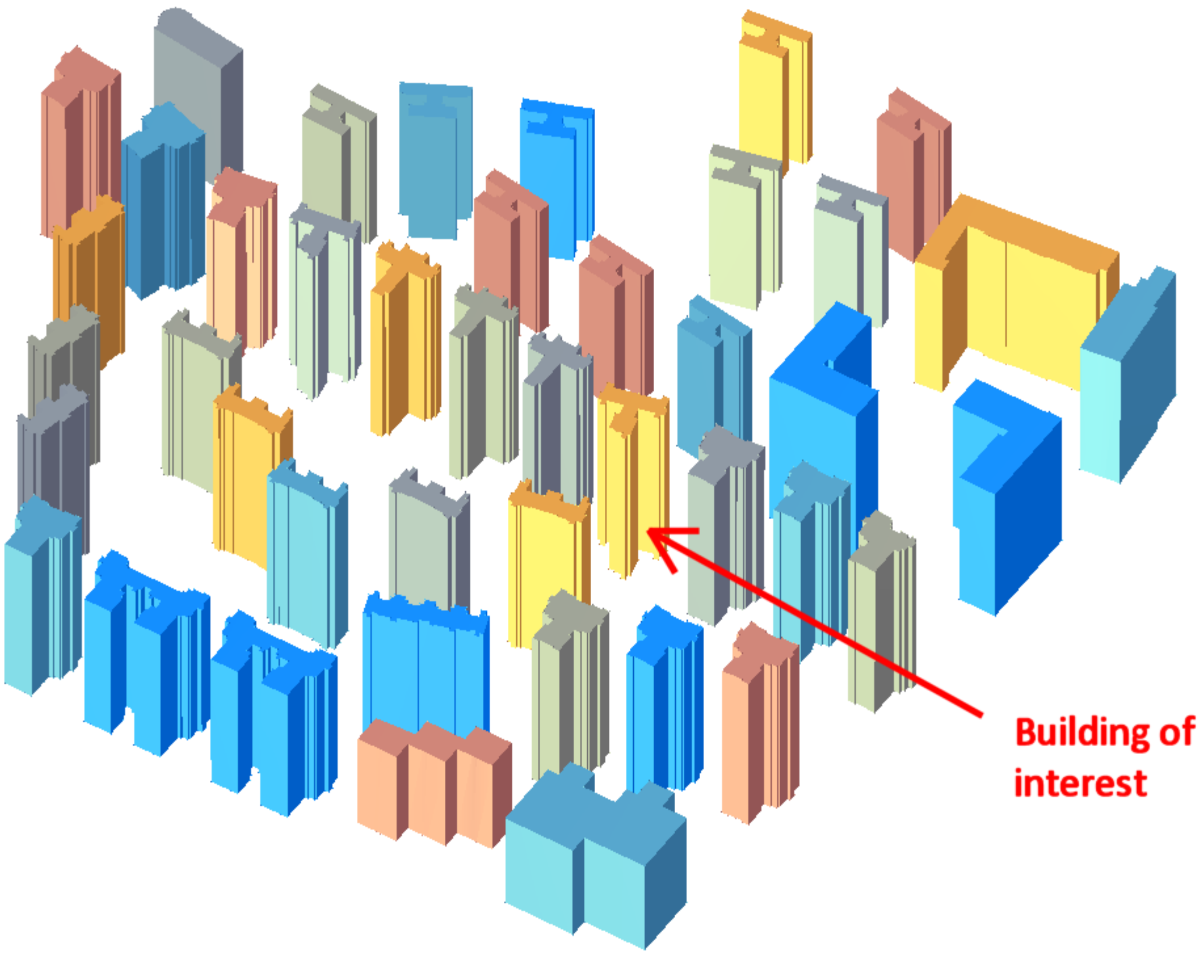
- Wind 5 m/s from the SW, log-law, roughness ht 0.03m



Typical Wind Case

Lecture

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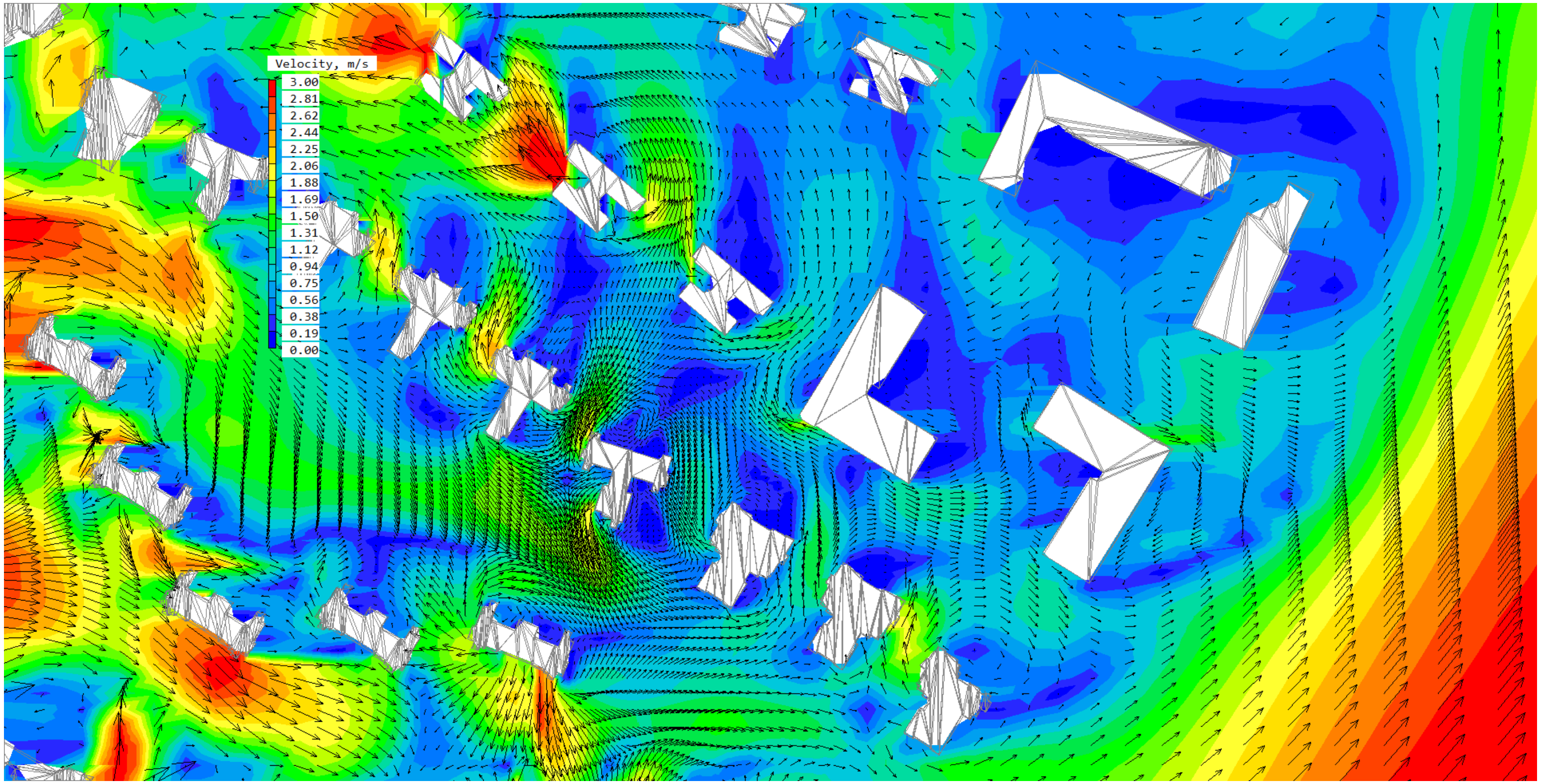
- Wind 1.5m above ground, around building of interest



Foliage object

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- Specifies drag of leaves on air movement
- Associated turbulence generation
- Cooling power (W/m^3)
- Humidity source due to evapotranspiration

Sun object

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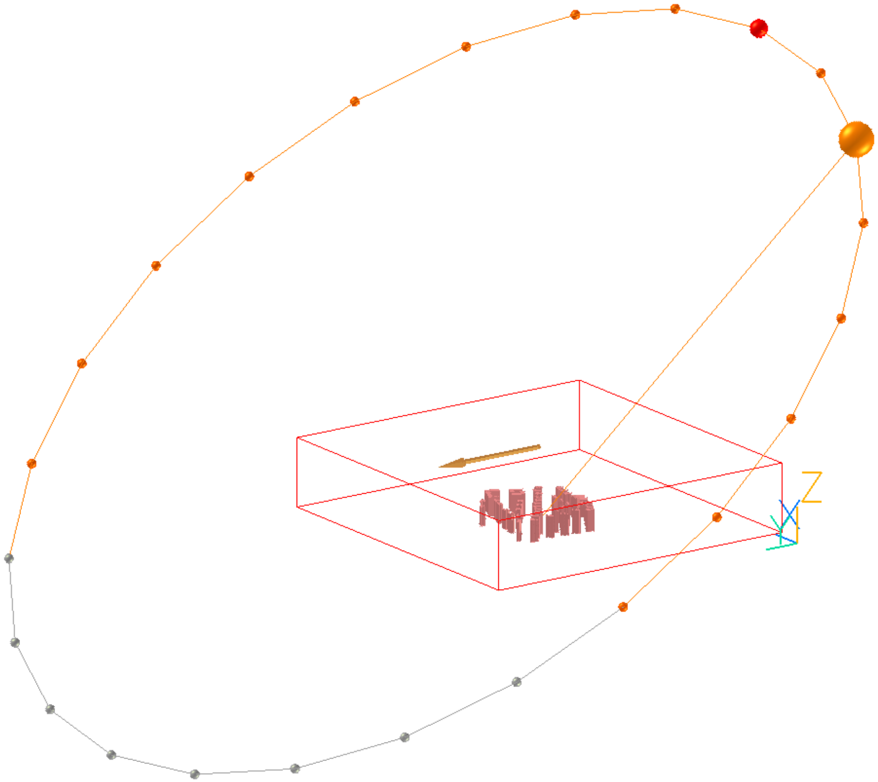
- Sun model calculates solar gain on buildings and ground
- Sun shown as golden ball at correct azimuth and altitude
- User specifies - latitude, time of day, and clear/cloudy



Sun object

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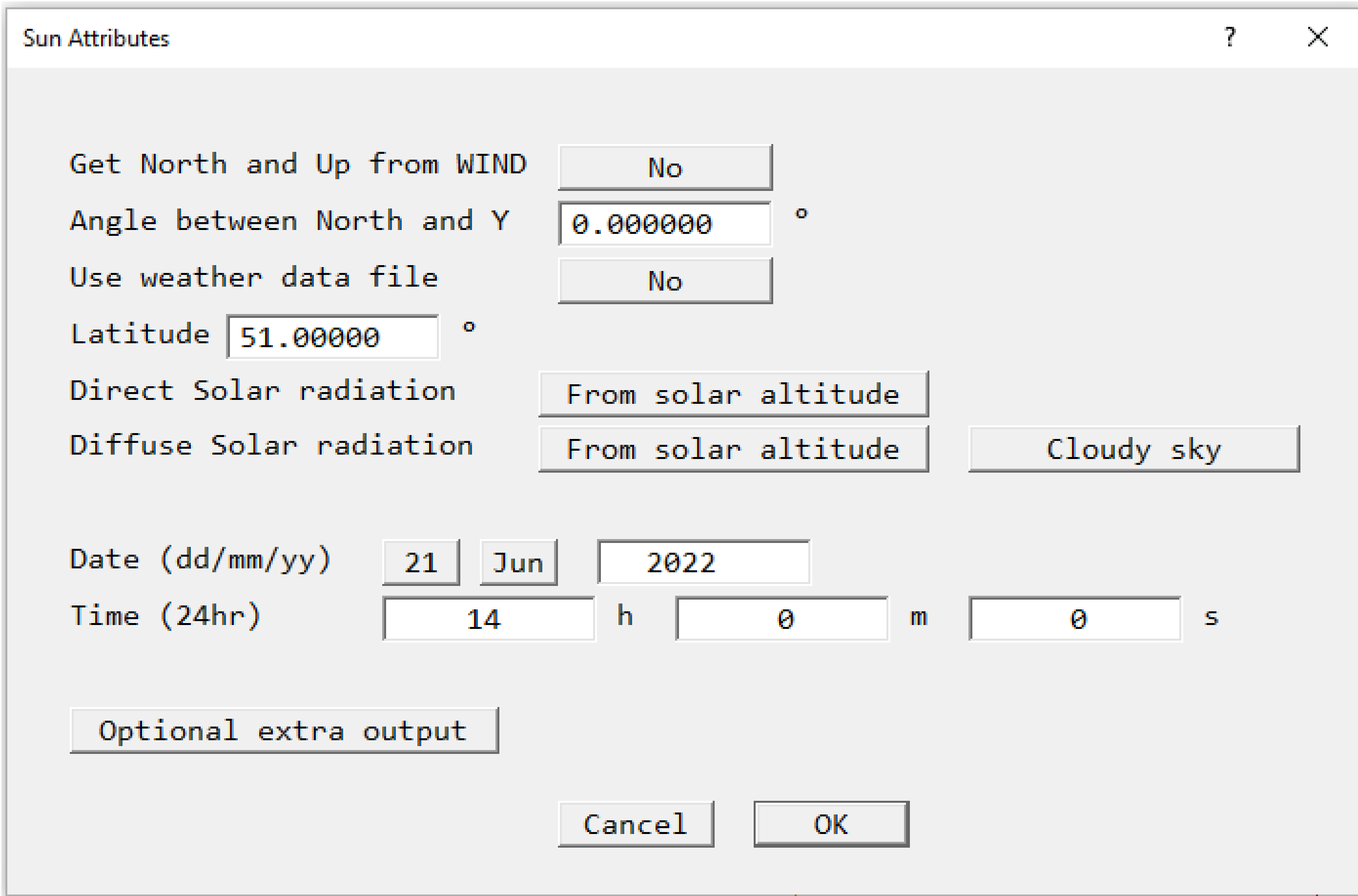
- Sun object attributes



Sun object

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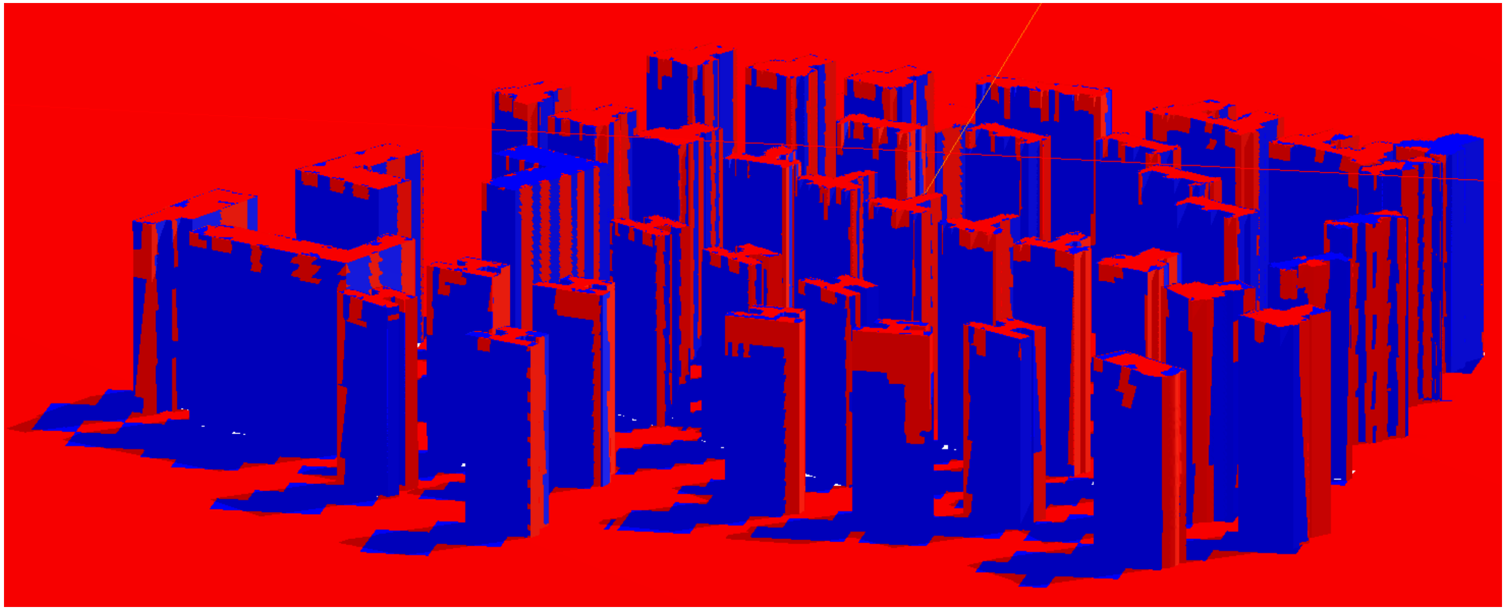
- Shadows are calculated by the sun model
- Blue areas represent shadows with no solar gain
- *This image produced by contouring LIT.*



Example – Culiacan Canopy

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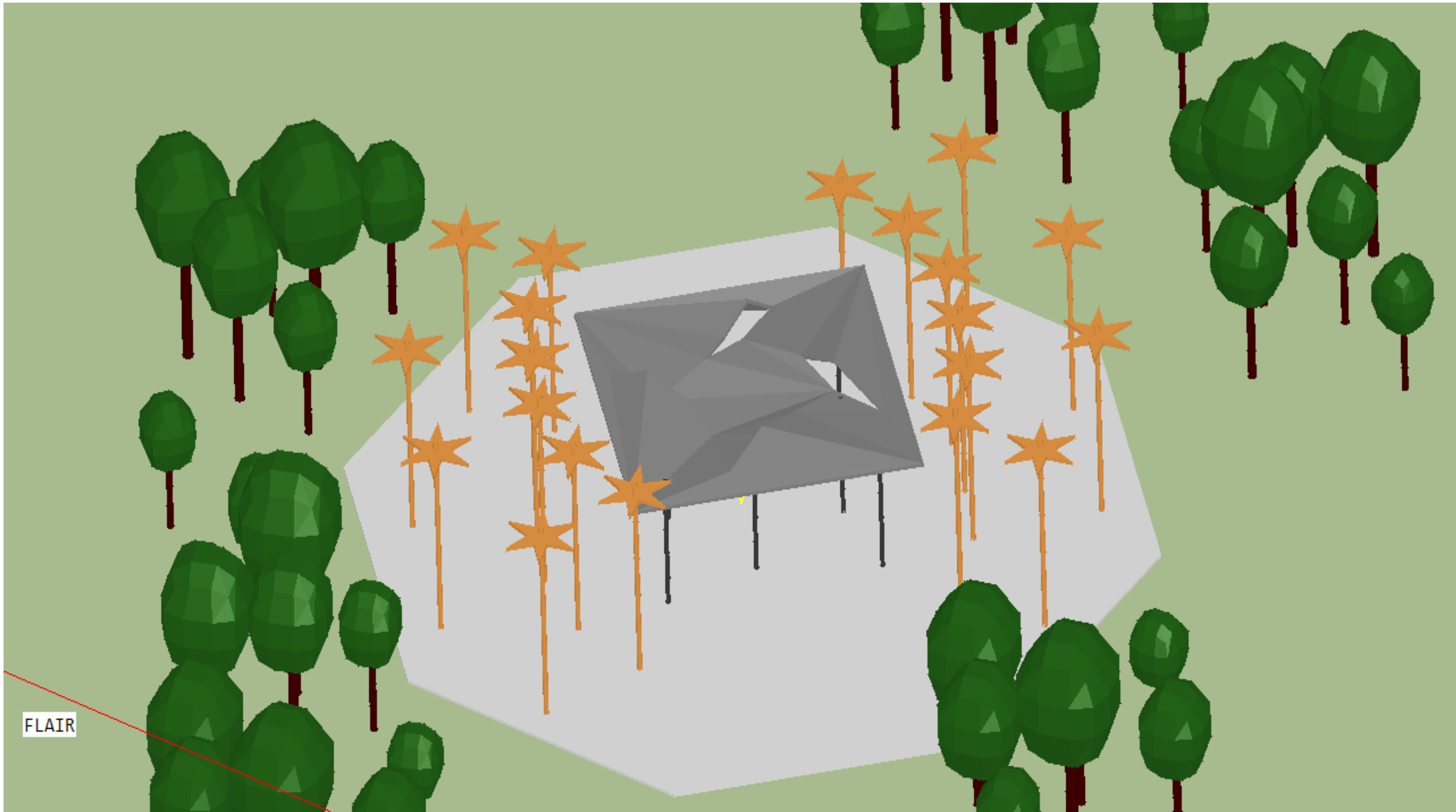
- Pedestrian comfort beneath metal canopy with foliage surround (Culiacan, Mexico)



Example – Culiacan Canopy

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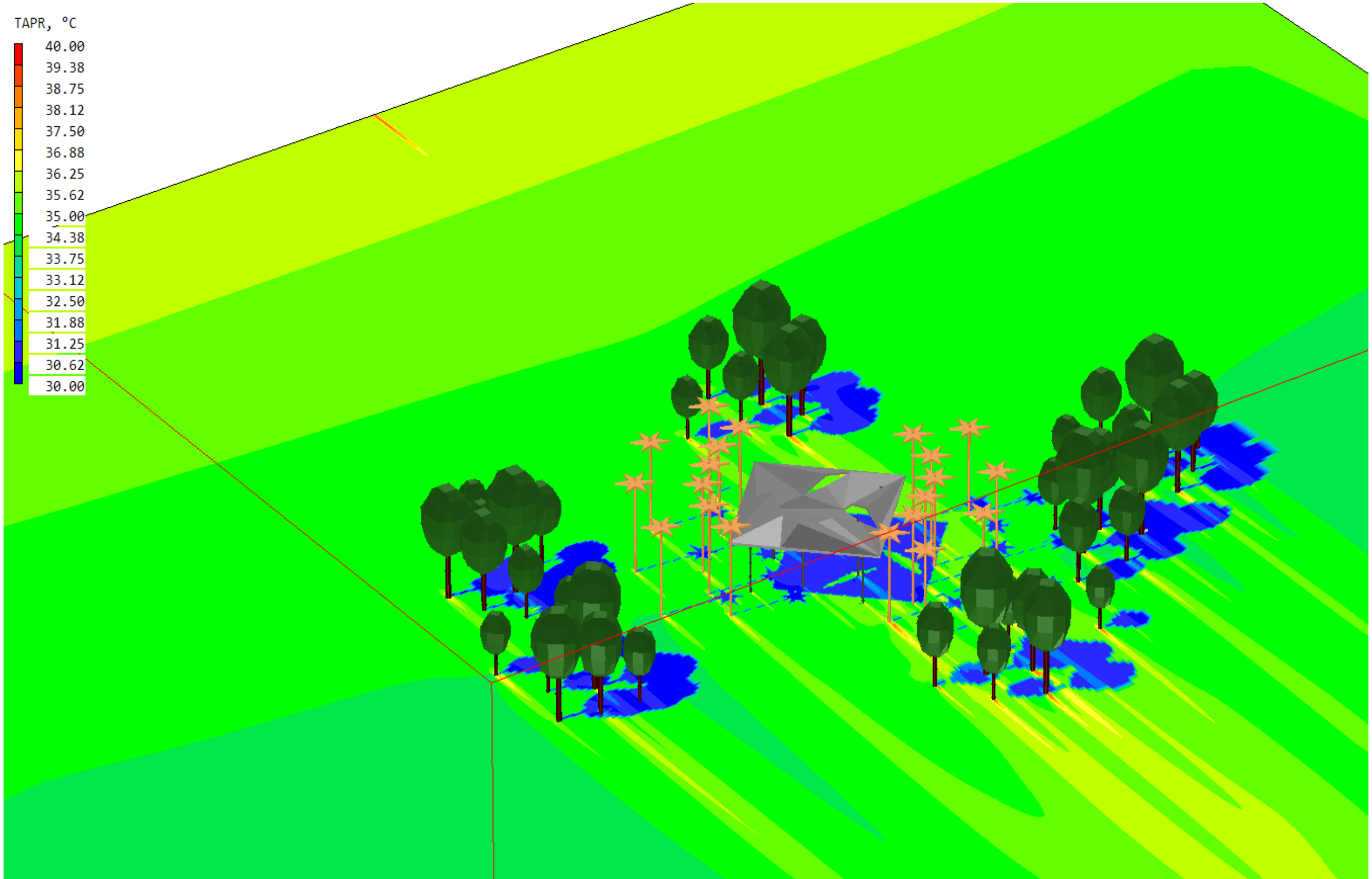
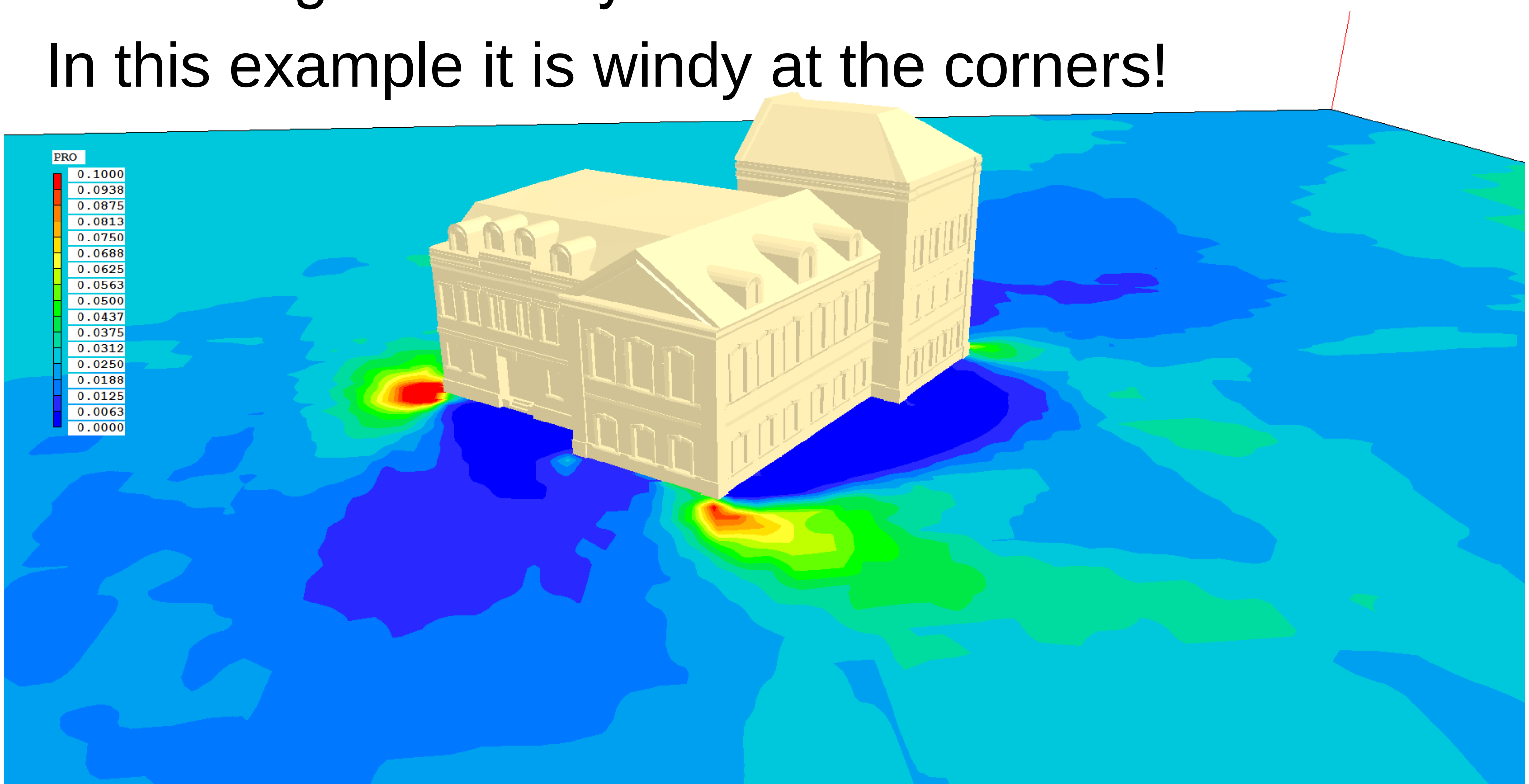
- Apparent temperature



Pedestrian Wind Comfort

- Statistical averaging of predictions for several wind directions
- Can generate parameters such as “Probability of exceeding” a velocity threshold
- In this example it is windy at the corners!



Pedestrian Wind Comfort
Lawson Criteria

- The Lawson Comfort Criteria specify a range of pedestrian activities - for each, a wind speed and maximum frequency of exceedance is defined
- If wind speed exceeds the threshold for the activity, deemed unacceptable
- The default criteria are:

Activity	Band	Probability	Threshold Wind Speed
Roads and Car Parks	A -> 1	6%	10.95 m/s
Business walking	B ->2	2%	10.95 m/s
Pedestrian walk-through	C -> 3	4%	8.25 m/s
Pedestrian standing	D -> 4	6%	5.6 m/s
Sitting	E -> 5	1%	5.6 m/s

- Again Lawson requires runs for all (usually 8 or 16) wind directions

Pedestrian Wind Comfort
Lawson Criteria

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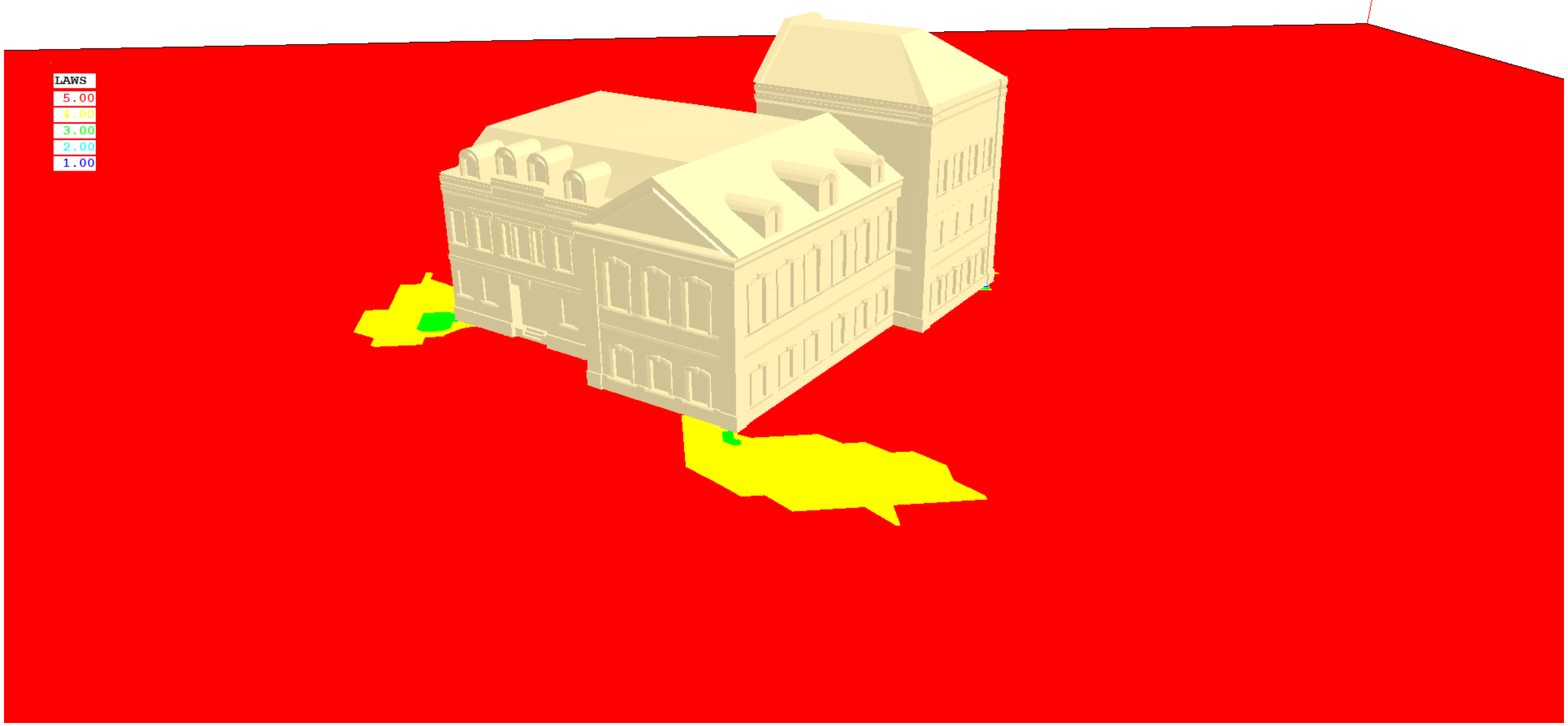
- Plot of Lawson regions for mansion case
- Easy to see “comfortable areas” and “windy areas”
- “Sitting” would not be comfortable at the corners!



END OF LECTURE