CHAM

Modelling Wind

Why Model Wind?

CHAM

- Effect of building on its environment
- Natural ventilation in apartments
- Pedestrian wind comfort
- Pressures on facades
- “Urban Heat Island” studies
- Pollution in street canyons

- This lecture will cover the basics, and concentrate on the first of the above points.

Modelling the Boundary Layer

CHAM

- Model atmospheric boundary layer under neutral stability conditions
- (Stable and unstable conditions require thermal modelling and are more complicated)
- On terrain surface, need "fully-rough" wall function to provide boundary conditions for the velocity components and the turbulence variables
- Suitable for a near-wall layer in local equilibrium defined in terms of the effective aerodynamic roughness height z_0

Wind Velocity Profiles

CHAM

Log Law

$$\frac{u}{u_r} = \frac{\ln(z/z_o)}{\ln(z_r/z_o)}$$

Power Law

$$\frac{u}{u_r} = \left(\frac{z}{z_r}\right)^{\alpha}$$

- α is the power-law exponent
- z_0 is the roughness height
- z_r is the reference height

- Profile can also be defined piecewise-linear from file

Roughness Height

CHAM

- z_0 - a measure used in calculating the frictional force acting on the wind at the ground …
- and therefore, also used in specification of the wind profile

$$\frac{u}{u_r} = \frac{\ln\left(z/z_o\right)}{\ln\left(z_r/z_o\right)}$$

- One of many possible measures of surface roughness
- Roughness height is <u>very</u> approximately one-tenth of height of surface roughness elements
- Generally convenient to use the "Davenport-Wieringa" classification

Roughness Height

CHAM

- Davenport-Wieringa roughness classification

z_0 (m)	Classification	Landscape
0.0002	sea	sea, paved areas, snow-covered flat plain, tide flat, smooth desert
0.005	smooth	beaches, pack ice, morass, snow-covered fields
0.03	open	grass prairie or farm fields, tundra, airports, heather
0.1	roughly open	cultivated area with low crops and occasional obstacles (single bushes)
0.25	rough	high crops, crops of varied height, scattered obstacles such as trees or hedgerows, vineyards
0.5	very rough	mixed farm fields and forest clumps, orchards, scattered buildings
1.0	closed	regular coverage with large-sized obstacles with open spaces roughly equal to obstacle heights, suburban houses, villages, mature forests
≥ 2	chaotic	centers of large towns and cities, irregular forests with scattered clearings

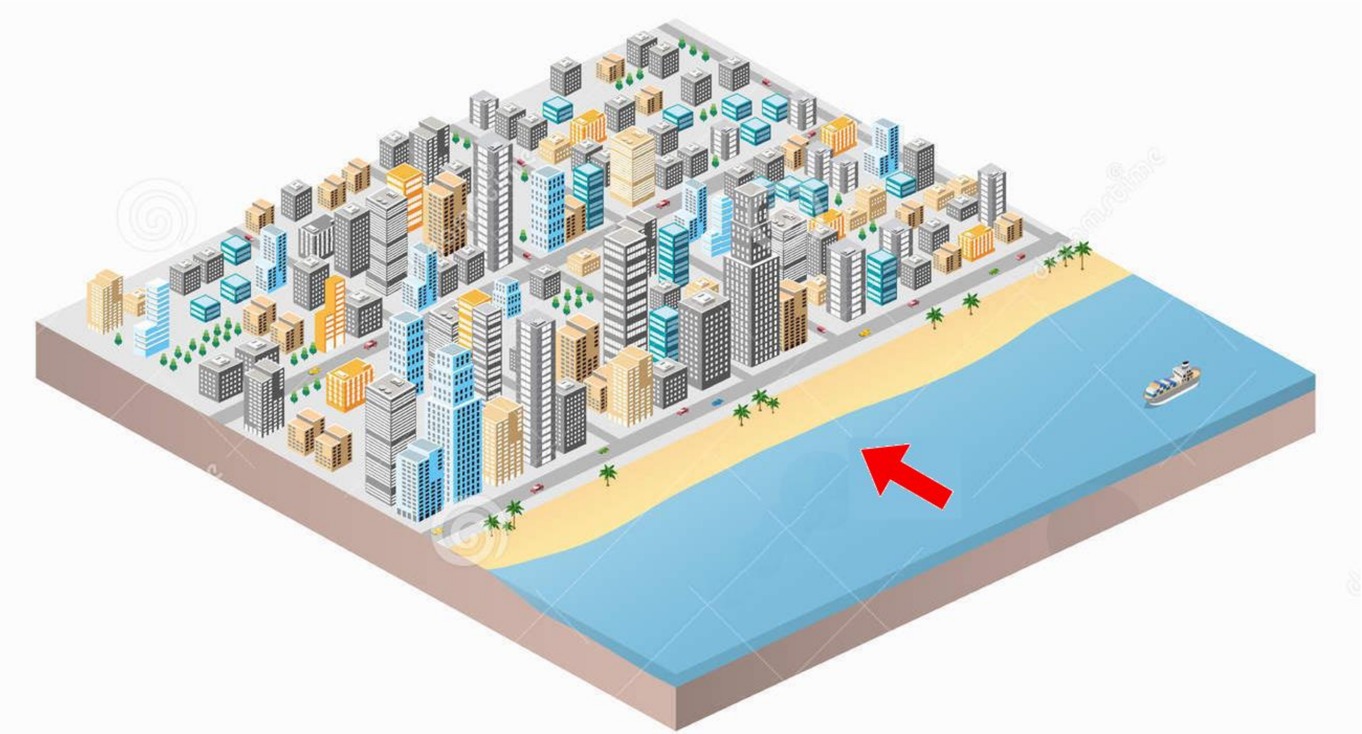
Roughness Height

CHAM

- Need to consider typical roughness height of ground areas between the buildings modelled
- Separately, need to consider typical ground roughness height <u>upwind</u> of the solution domain
- The latter creates the wind profile specified on the upwind boundaries of the solution domain

Roughness Height

- Example – buildings by the sea with on-shore wind
- Roughness height for the terrain - appropriate for areas between buildings
- Roughness height for wind profile - value for sea

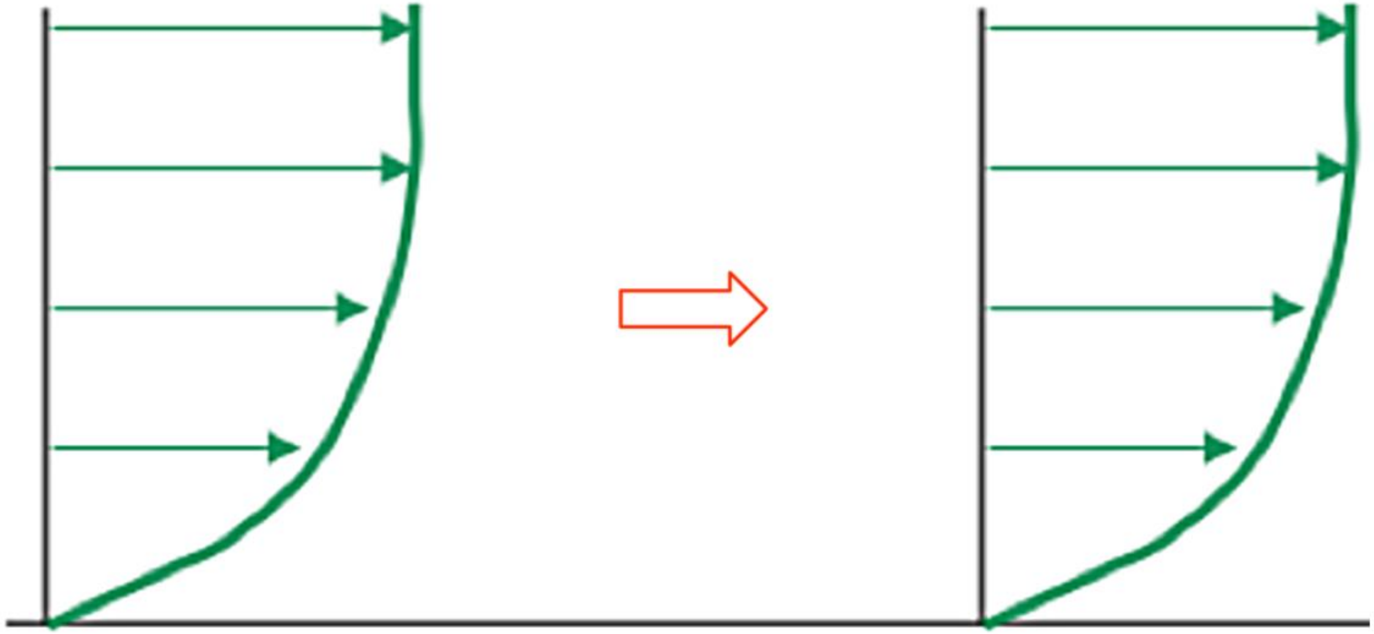


CHAM

Preserving the Profile

CHAM

- As wind blows over a flat terrain, the profile should be preserved.
- This can be achieved with a log-law profile if the roughness heights of the profile and the terrain match.



Friction on Building Surfaces

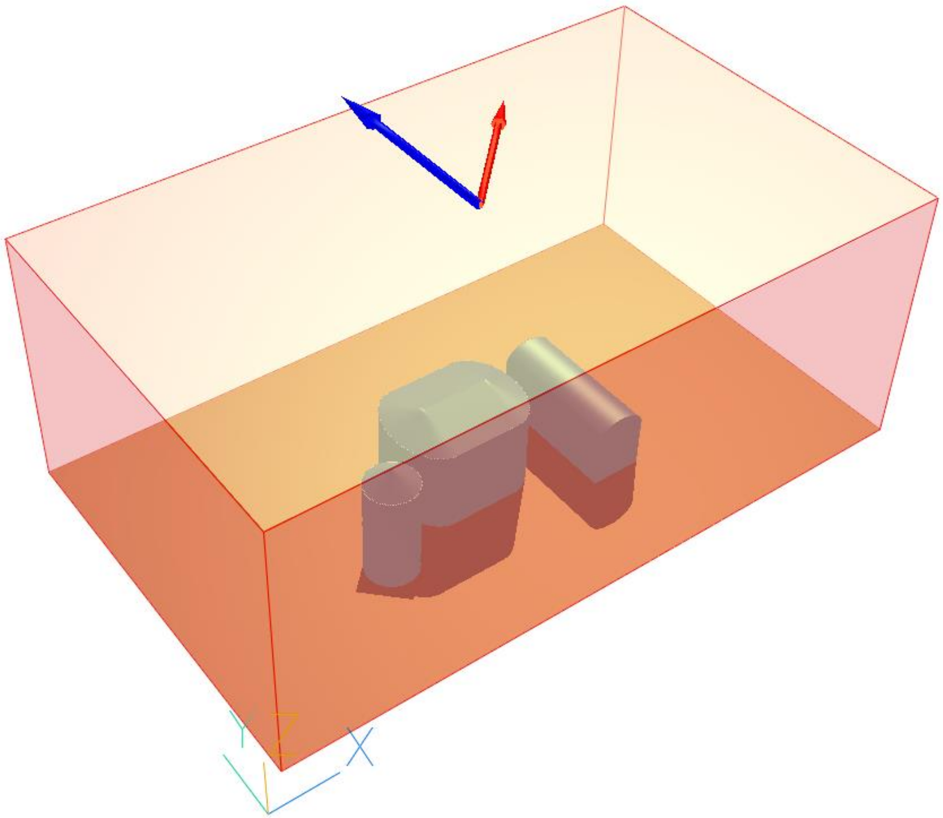
CHAM

- It is <u>incorrect</u> to use the "fully rough" wall functions discussed above for surfaces of buildings
- Instead, the "log-law" should be used
- Simply achieved by leaving default settings:
- "Coeff for auto wall functions" in <u>Sources Menu</u> should be default "Log Law", and
- "Wall function law" in <u>Object Attributes</u> for buildings should be "Default"

Wind Object

CHAM

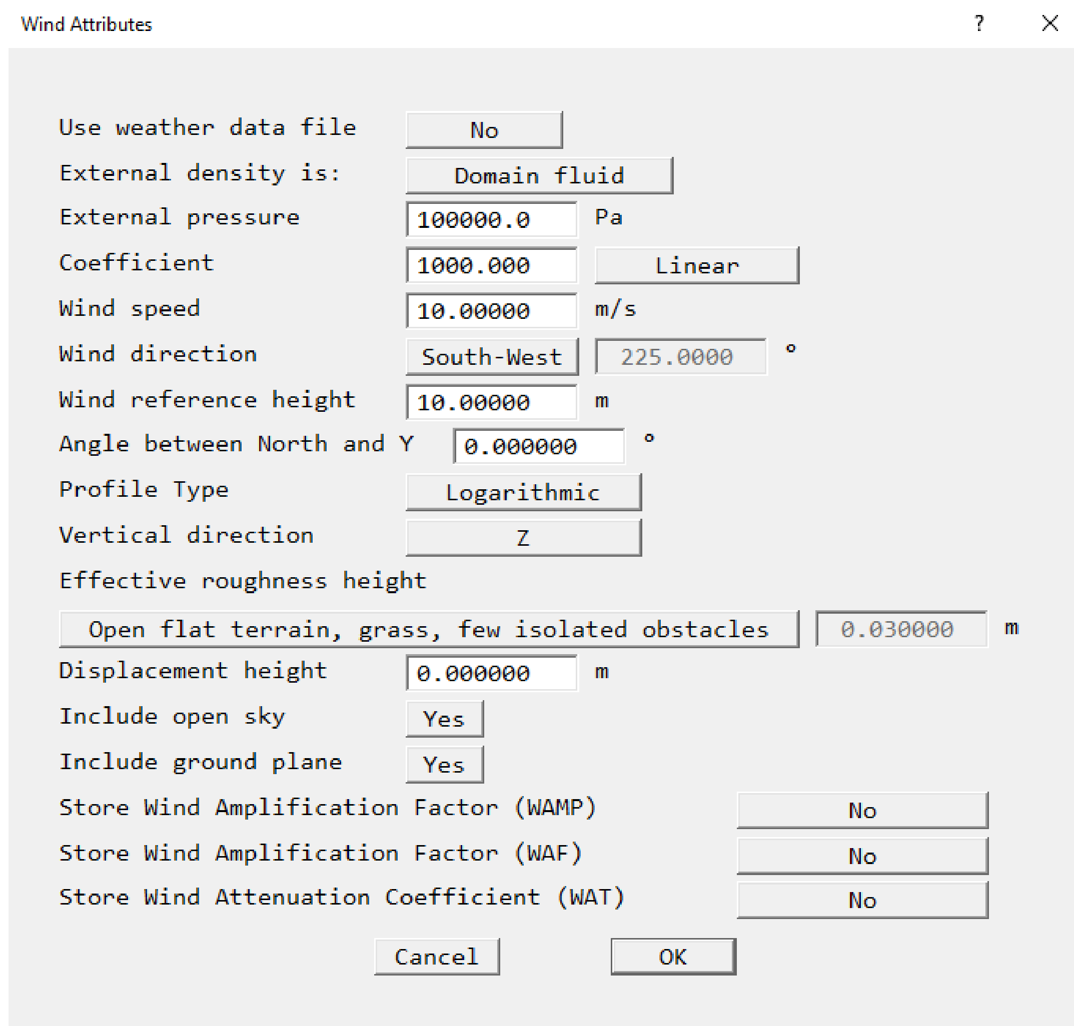
- Wind settings made using “Wind Object”
- Red arrow – wind direction
- Blue arrow - North



Wind Object

CHAM

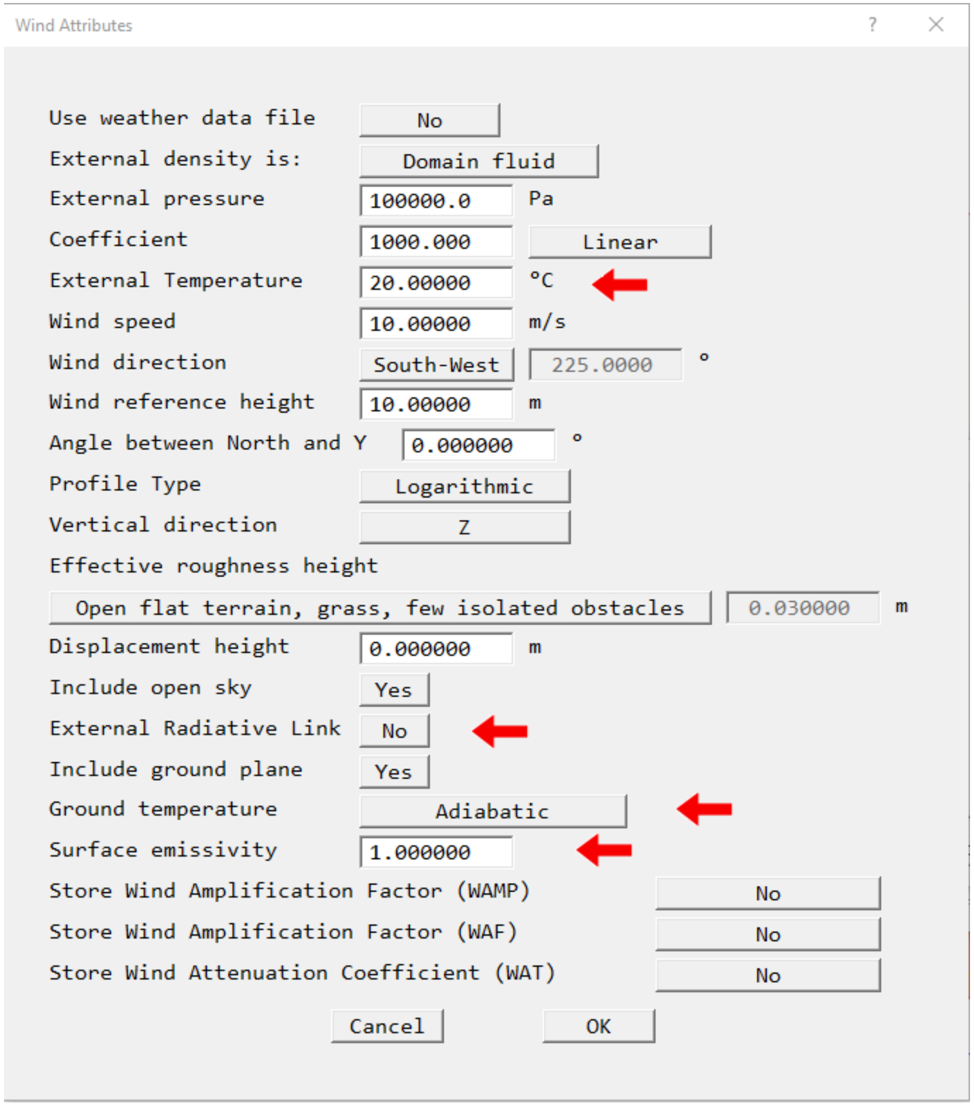
- Wind settings are in the “Attributes” panel for the Wind Object
- Shown here with temperature not solved
- Context help “?” can be used to check on details



Wind Object

CHAM

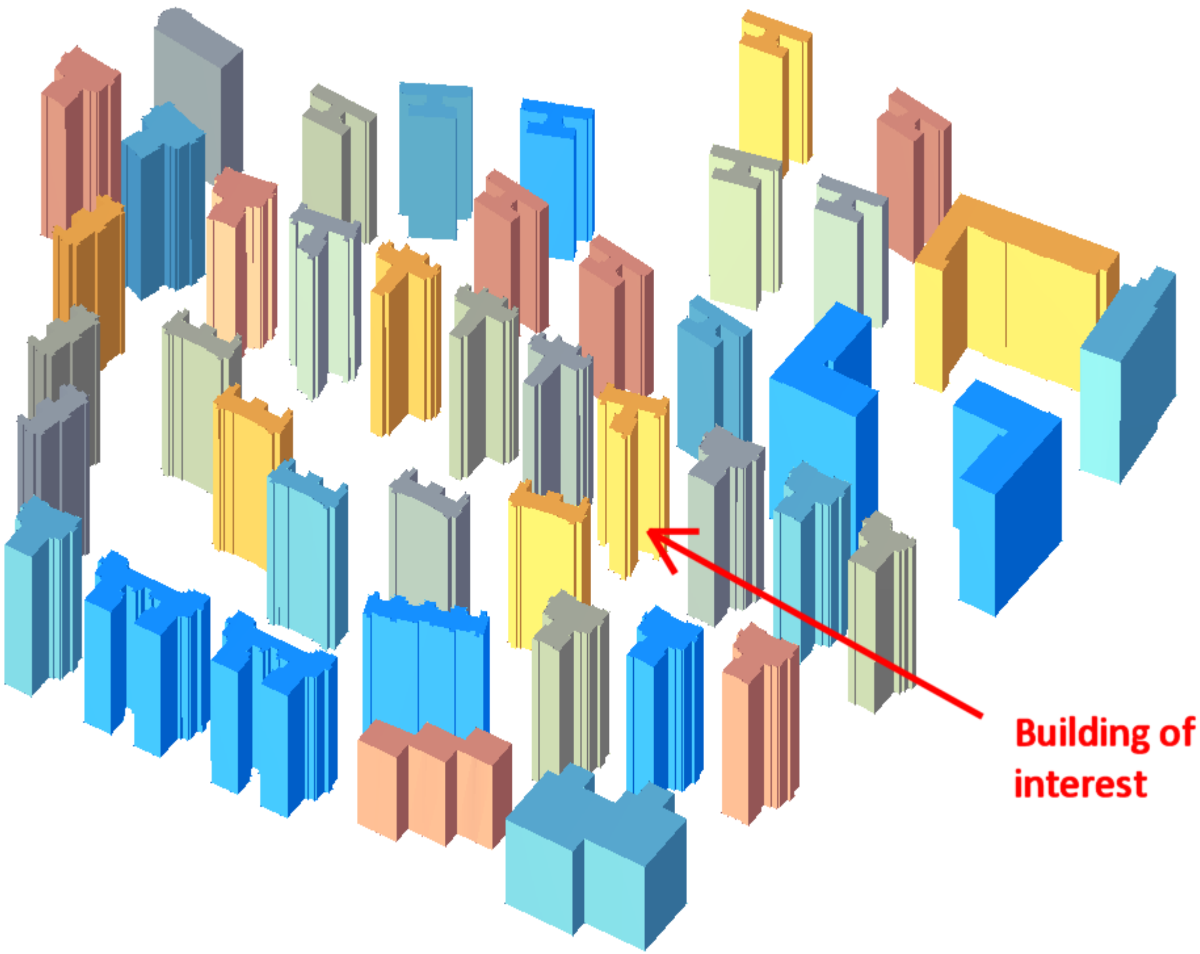
- With temperature and radiation solved (e.g. for Urban Heat Island models), additional buttons appear



Meshing

CHAM

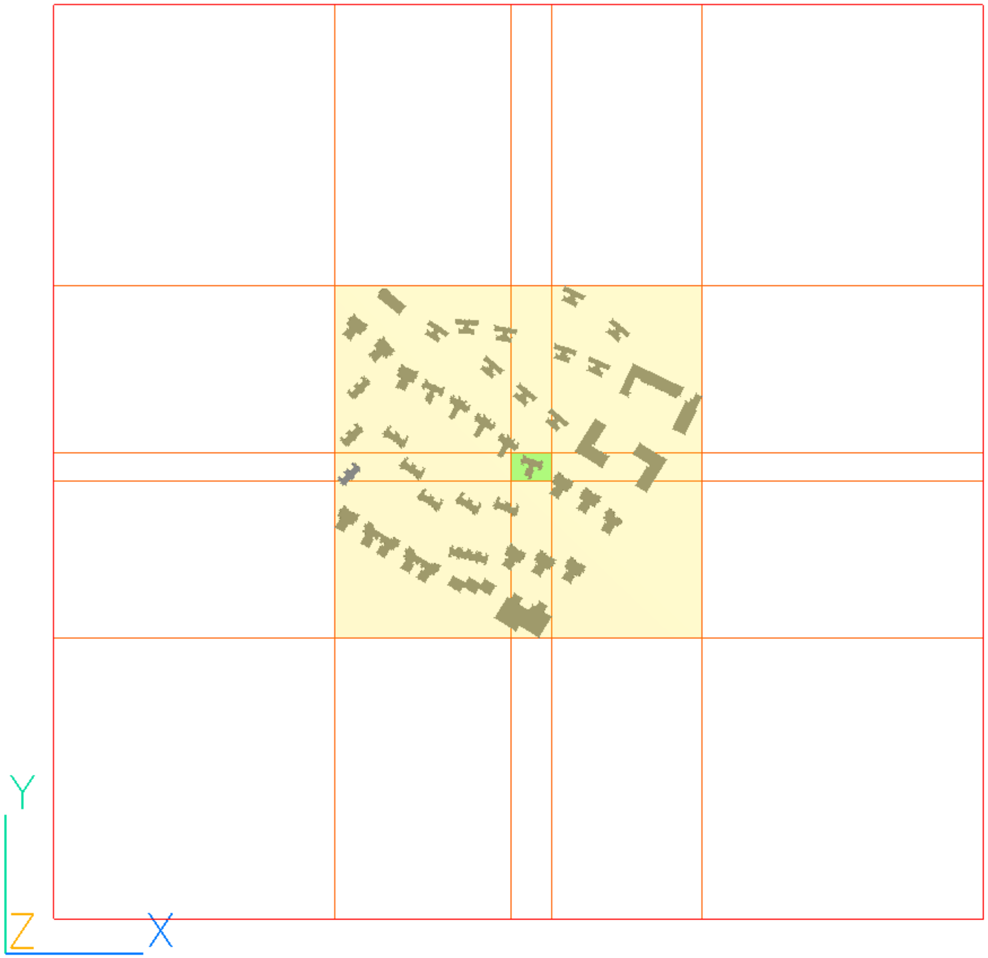
- Example – group of city towers



Meshing

CHAM

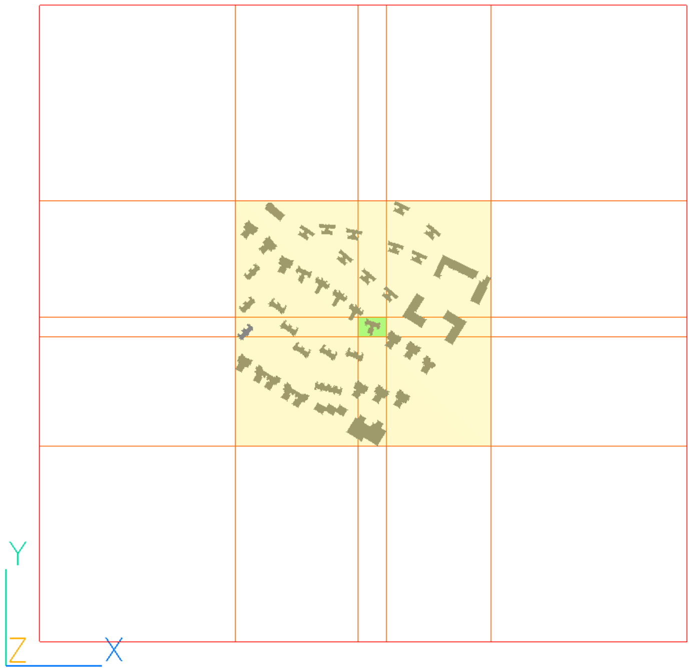
- Solution domain and mesh regions might typically look like this:



Meshing

CHAM

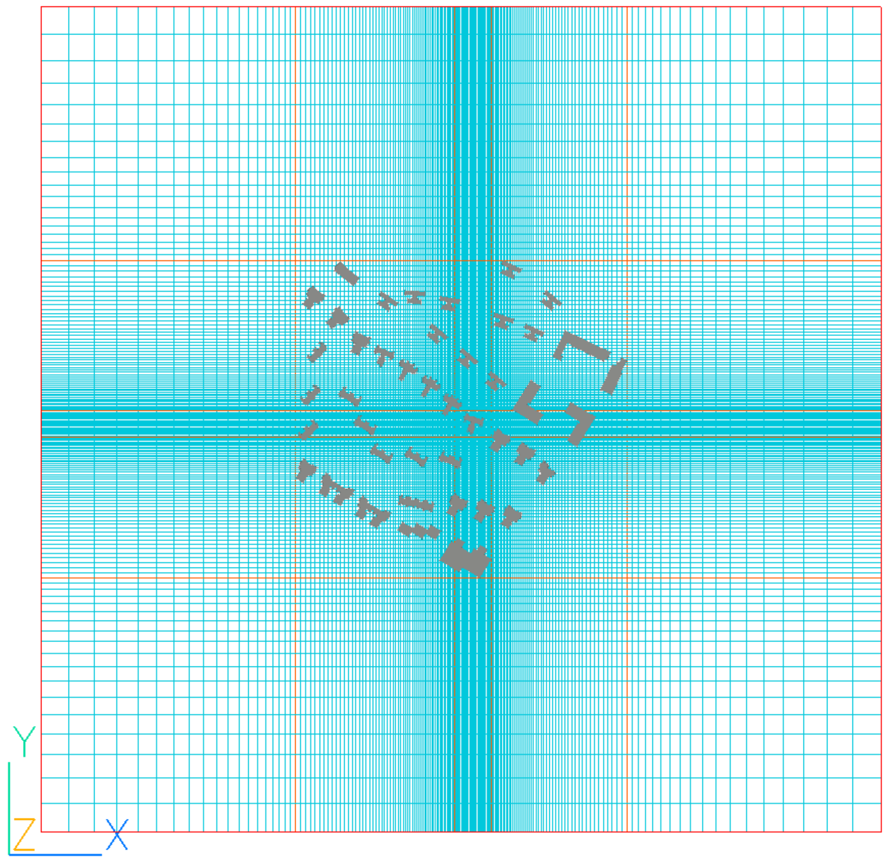
- Create two Null objects to assist mesh generation
- Building of interest contained by green Null object
- This region might have uniform fine mesh
- Surrounding buildings contained by yellow Null object
- Mesh here expands outwards gently
- Mesh continues to expand (faster) in outermost regions
- Use Geometric expansion



Meshing

CHAM

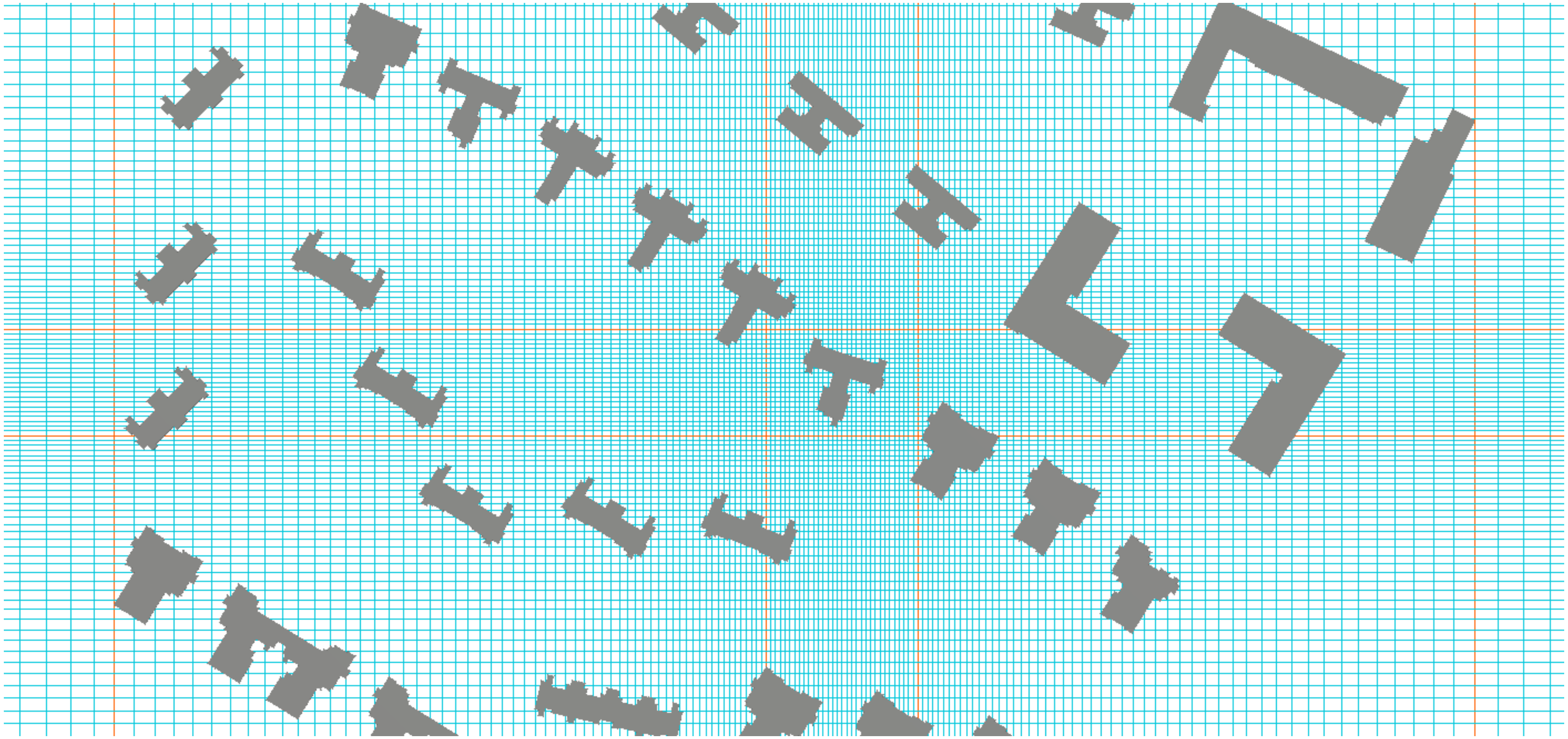
- The mesh will typically look something like this
- Note the smooth gradation in mesh size



Meshing

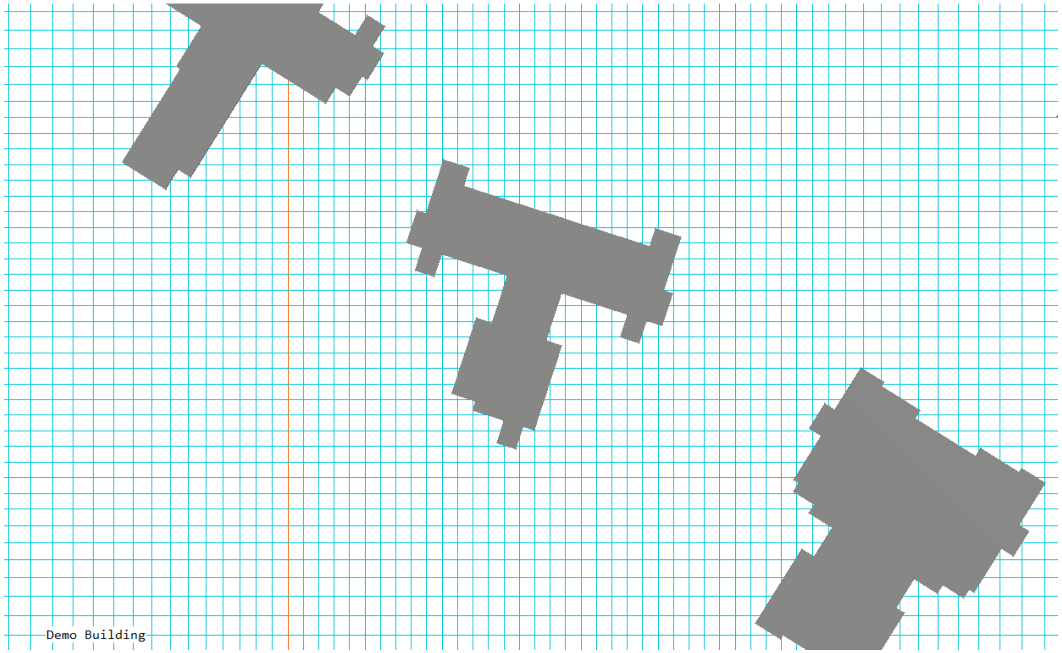
CHAM

- Mesh in central regions



Meshing

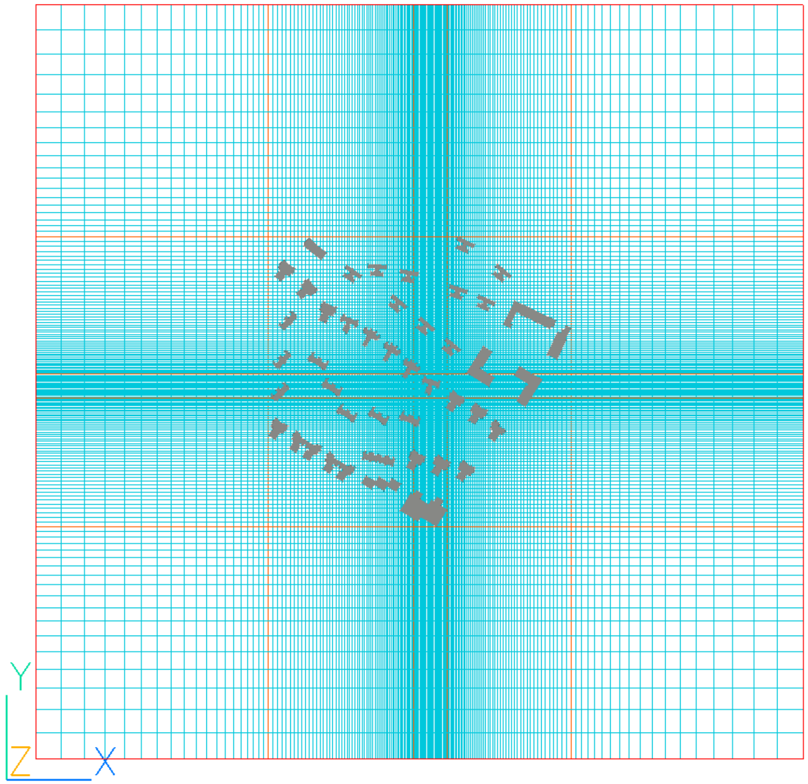
- Mesh around building of interest
- Note no change of mesh size across region boundaries
- These are 2m cells – you might want finer
- Note – this example has about 1.1 million cells in total



CHAM

Meshing

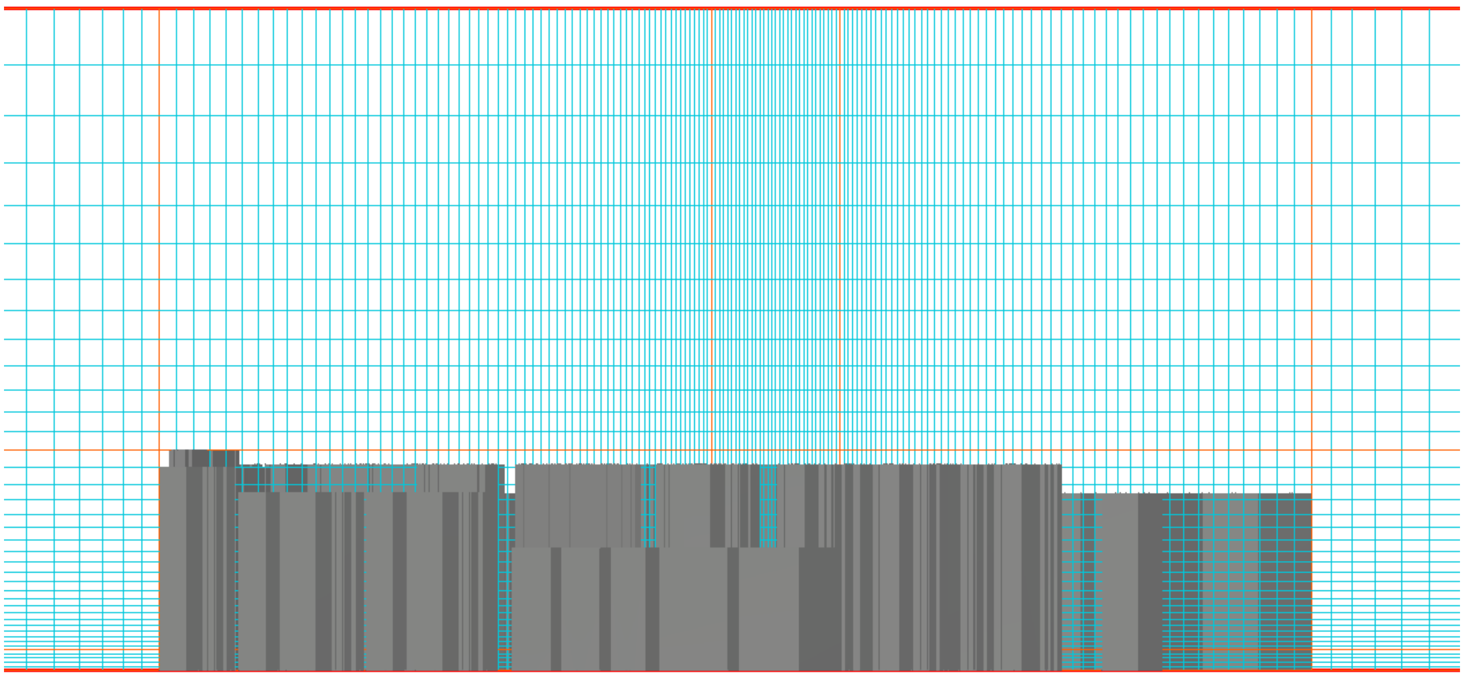
- Grid uniform in central region
- Geometric expansion ~ 1.03 – 1.05 in intermediate
- Geometric expansion ~ 1.1 in outer regions



Meshing – Vertical Direction

CHAM

- In this example the domain height is 3x building height
- Region near ground is 10m with 5 uniform cells
- Geometric expansion in regions above, 1.1 at top
- Regions created by setting heights for the Null objects



Relaxation

CHAM

- Golden rule for wind cases:

- Switch off Automatic Convergence Control (CONWIZ)
- Set relaxation for velocities U1, V1, W1 manually
- Use “FALSDT” relaxation with amount 0.1 seconds

- It is worth experimenting using 1 second
- (i.e. lighter relaxation)
- If this converges the run will be quicker

Plotting results at height above ground

- It may be required to plot velocity contours at typical pedestrian height
- e.g. 1.5 or 2m above the ground

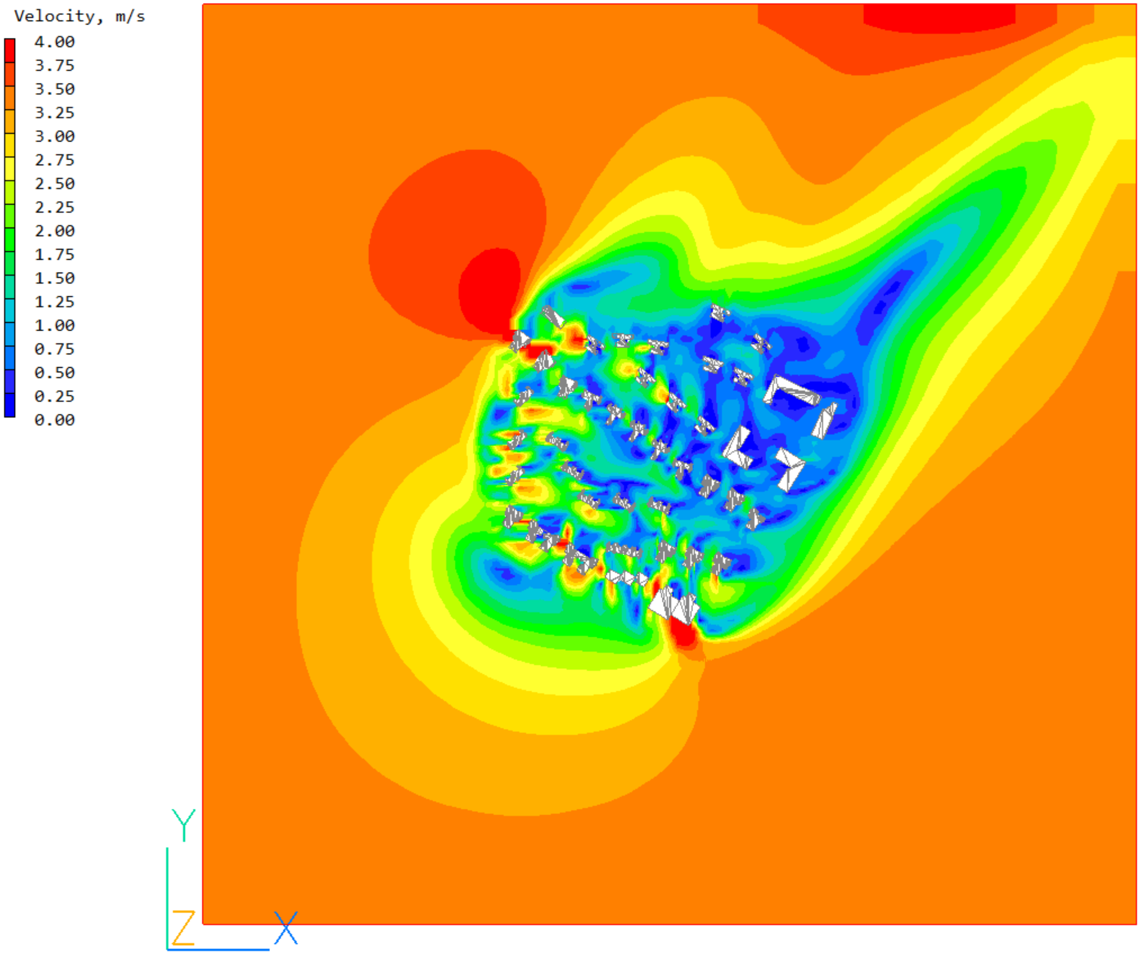
- This is easily done by creating a Plotting Surface object at this height
- If you have a terrain object, the Plotting Surface object can be a duplicate, raised 1.5m or 2m higher

- In the Viewer, right-click on the object, then select “Surface Contours”

Typical Velocity Distribution

CHAM

- Wind 5 m/s from SW – velocities at 1.5m height



Typical Velocity Distribution

CHAM

- Wind distribution around “Building of Interest”