INHALE

MAGIC

Envisaging a world with greener cities

Managing Air for Green Inner Cities

The development of physical tree and ground surface modules in Fluidity for urban modelling

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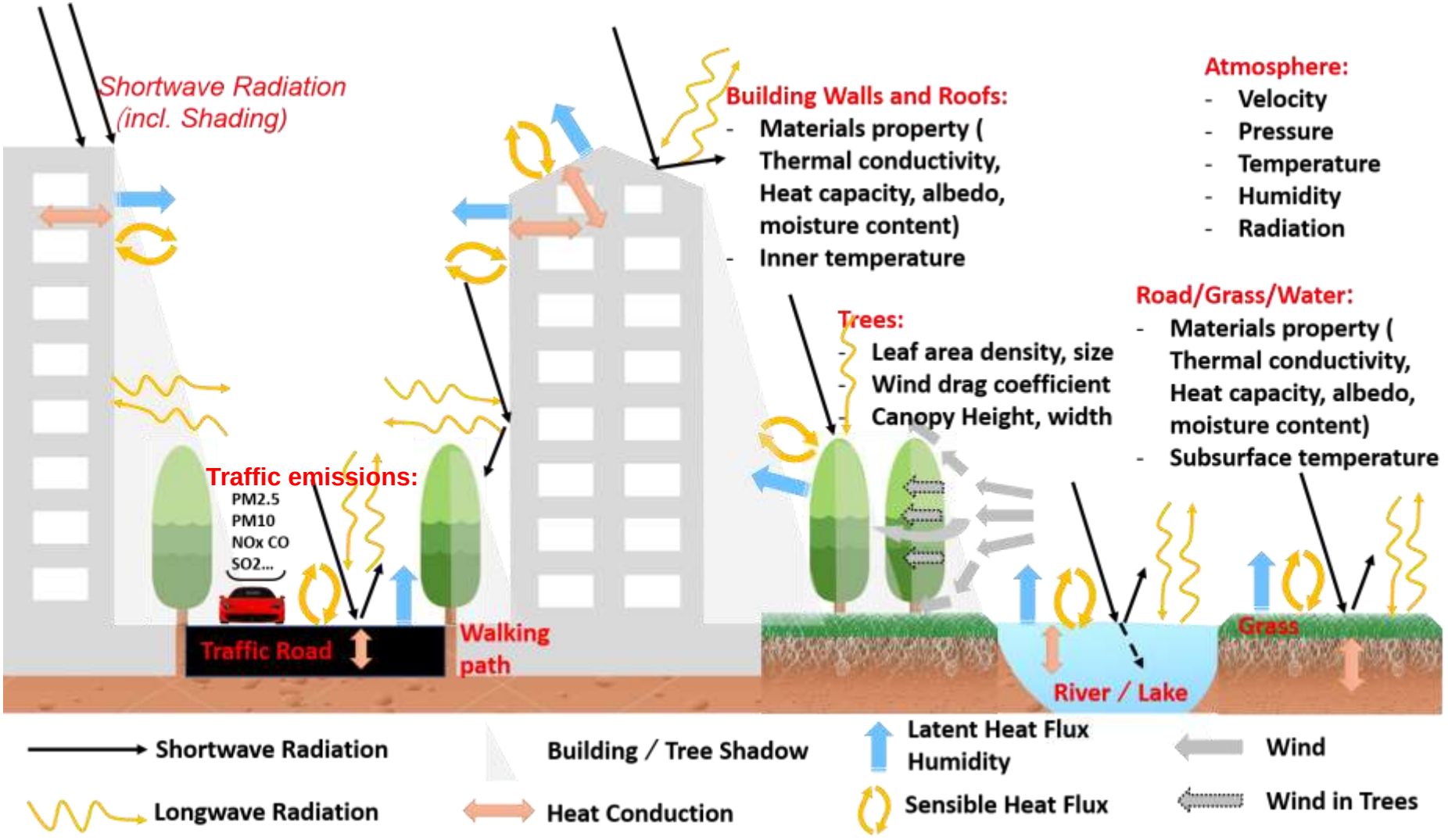
Conceptual illustration of the atmospheric physical processes in urban



Software/tool for generating the geometry and 3D mesh

Google Earth View

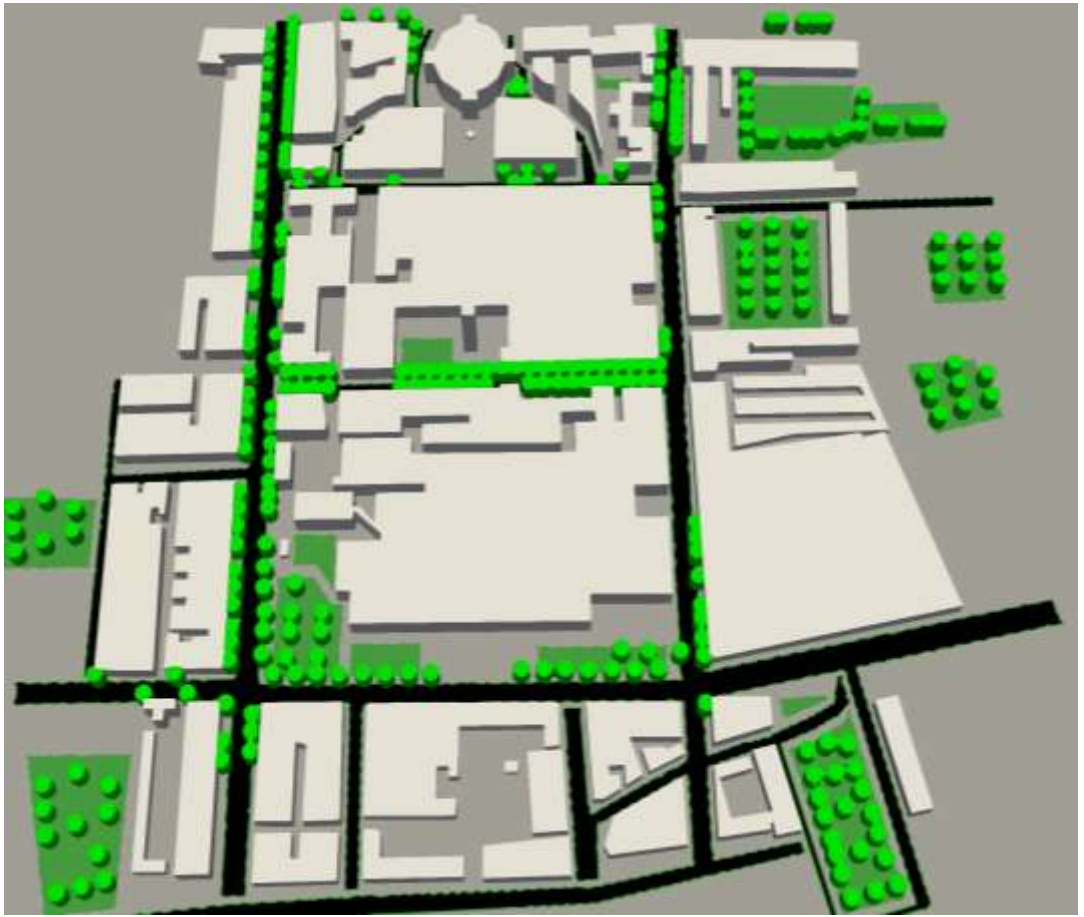
Geometry

Ocean

Software/tool for generating the geometry and 3D mesh

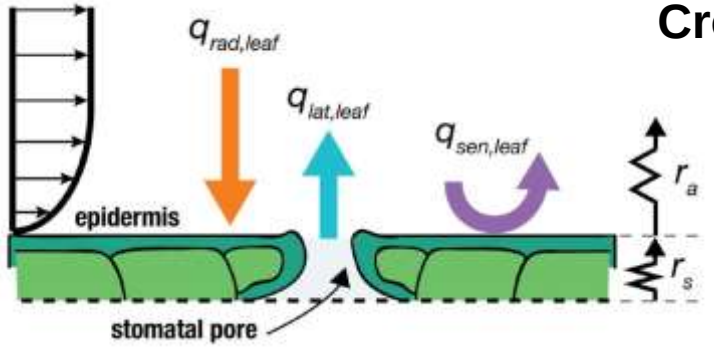
Google Map

Geometry

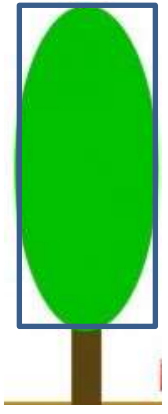


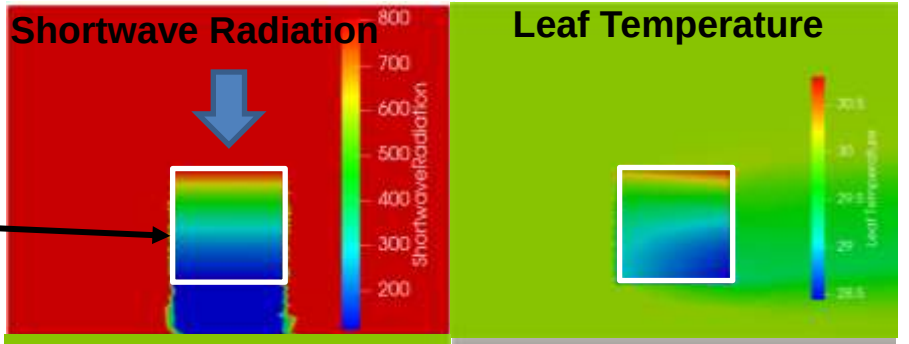
Tree modelling: trees' effects on velocity, temperature and Humidity

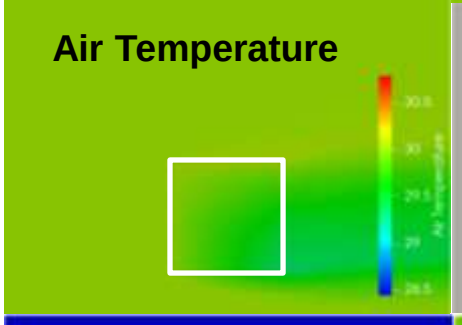
Energy balance on leaf surface

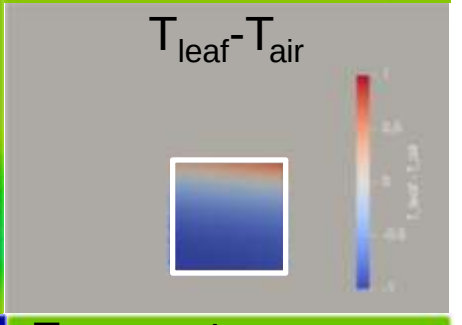


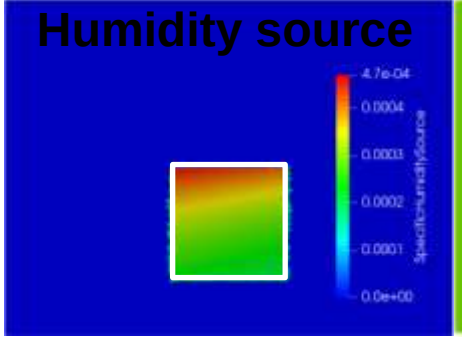
Cross section
Of a tree

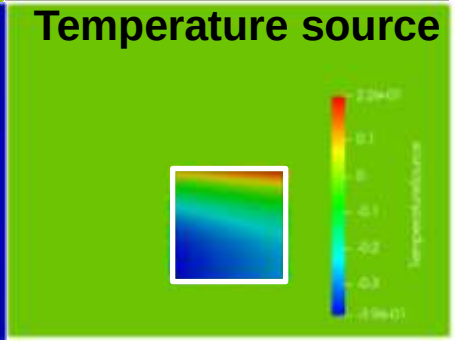












Momentum absorption term:

$$s_u = -\rho c_d a |\bar{u}| \bar{u}$$

Temperature source term:

$$s_T = a \cdot \frac{q_{sen,leaf}}{\rho c_p}$$

(T-T_{leaf}, velocity, leafsize)

Humidity source term:

$$s_w = a \cdot \frac{g_{v,leaf}}{\rho}$$

T_{leaf} -> leaf saturated vapour pressure
air humidity -> air vapour pressure

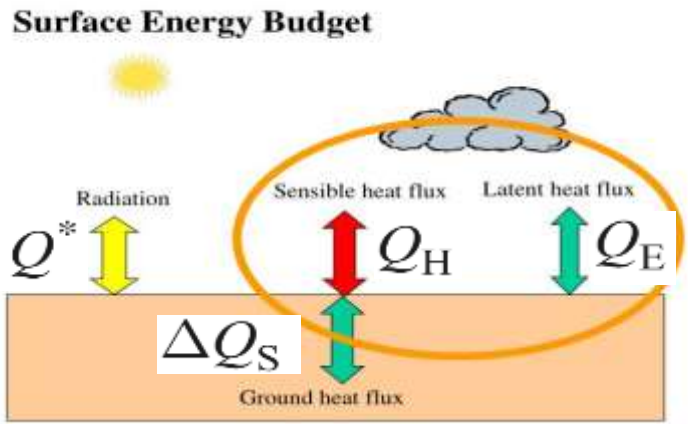
Manickathana at al, 2018

Physical processes in the land surface model

Leaf and Erell, 2018

Energy balance of ground surface:

$$Q^* = Q_H + Q_E + \Delta Q_S$$



Iteration until the surface temperature converge

- **Net radiative flux**

$$Q^* = Q^{'} - L_{\uparrow} = (K_{\downarrow} - K_{\uparrow} + L_{\downarrow} - L_{refl}) - L_{\uparrow}$$

$$L_{\uparrow} = \varepsilon_s \sigma T_s^4$$

$$K_{\uparrow} = \alpha K_{\downarrow}$$

$$L_{refl} = (1 - \varepsilon_s) L_{\downarrow}$$

- **Sensible heat flux**

$$Q_H = h_c (T_s - T_a) = \frac{\rho_a C_p (T_s - T_a)}{r_a}$$

- **Latent heat flux**

$$Q_E = \lambda_w ET = \frac{s(Q^* - \Delta Q_s) + \rho_a C_p \frac{(e_s - e_a)}{r_a}}{s + \psi\left(1 + \frac{r_s}{r_a}\right)}$$

- **Ground heat flux**

$$\Delta Q_s = \frac{\frac{\lambda}{z_{deep}}(T_s - T_{deep}) + \frac{Cv\, z_{deep}}{2\,\Delta t}(T_s - T_{mid}^{-})}{1 + \frac{z_{mid}}{z_{deep}} + \frac{Cv\, z_{mid}\, z_{deep}}{2\,\Delta t\, \lambda}}$$

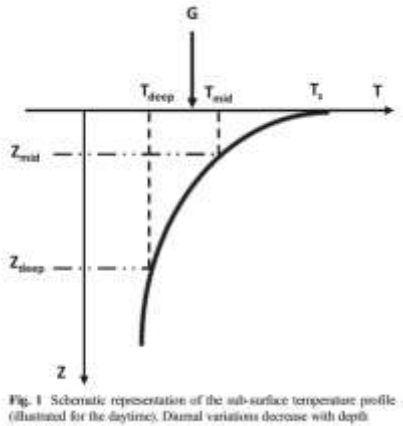
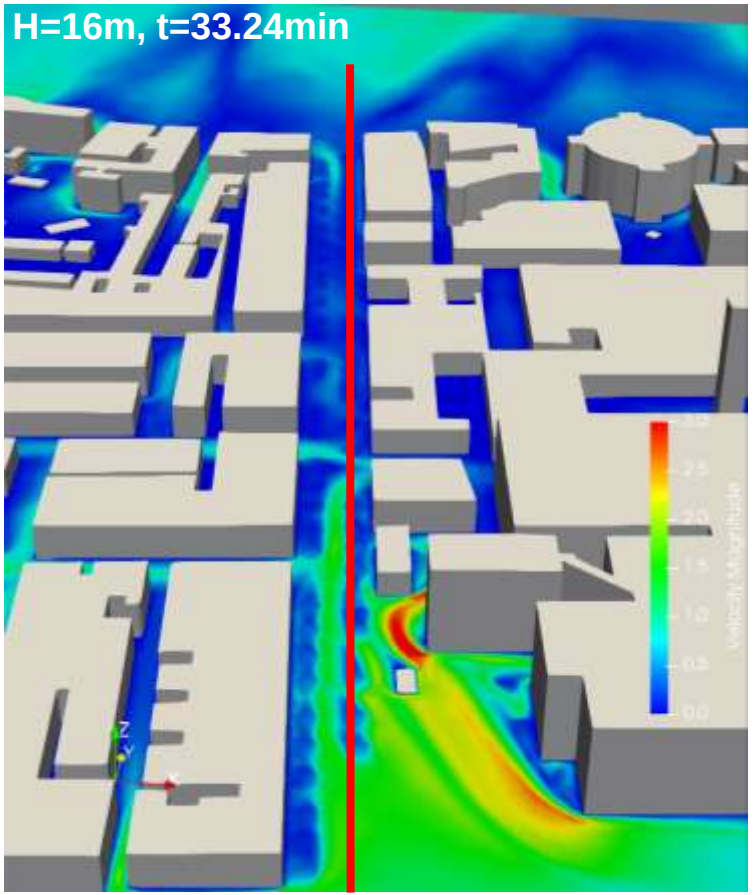


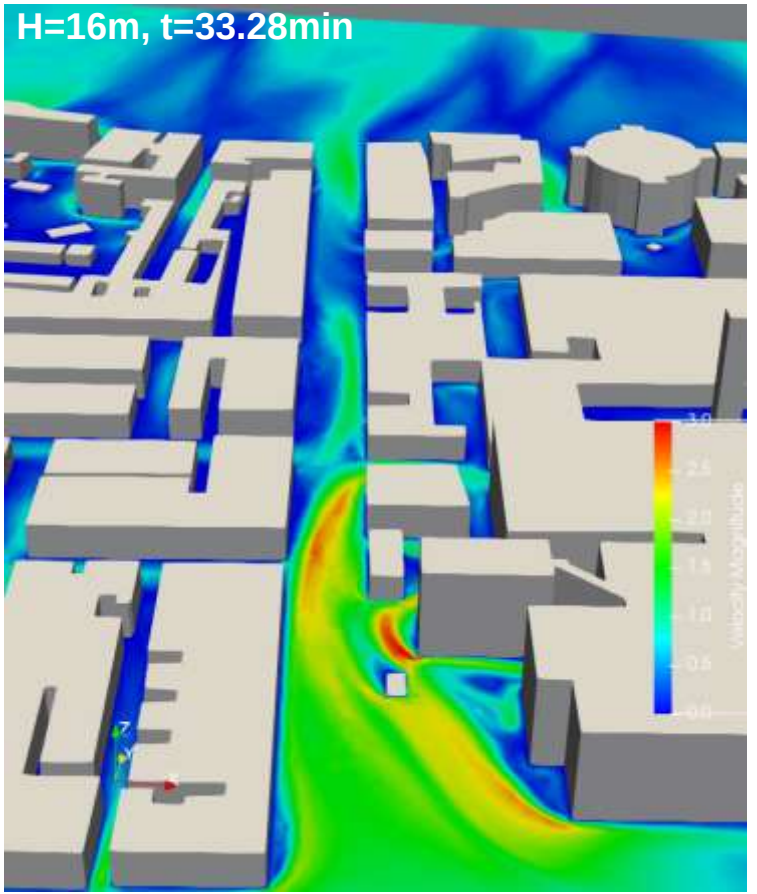
Fig. 1 Schematic representation of the sub-surface temperature profile (illustrated for the daytime). Diurnal variations decrease with depth

Tree modelling: Simulation over Queens's Gate with trees

With Trees



No Trees



Effect of tree species and distance on urban environment

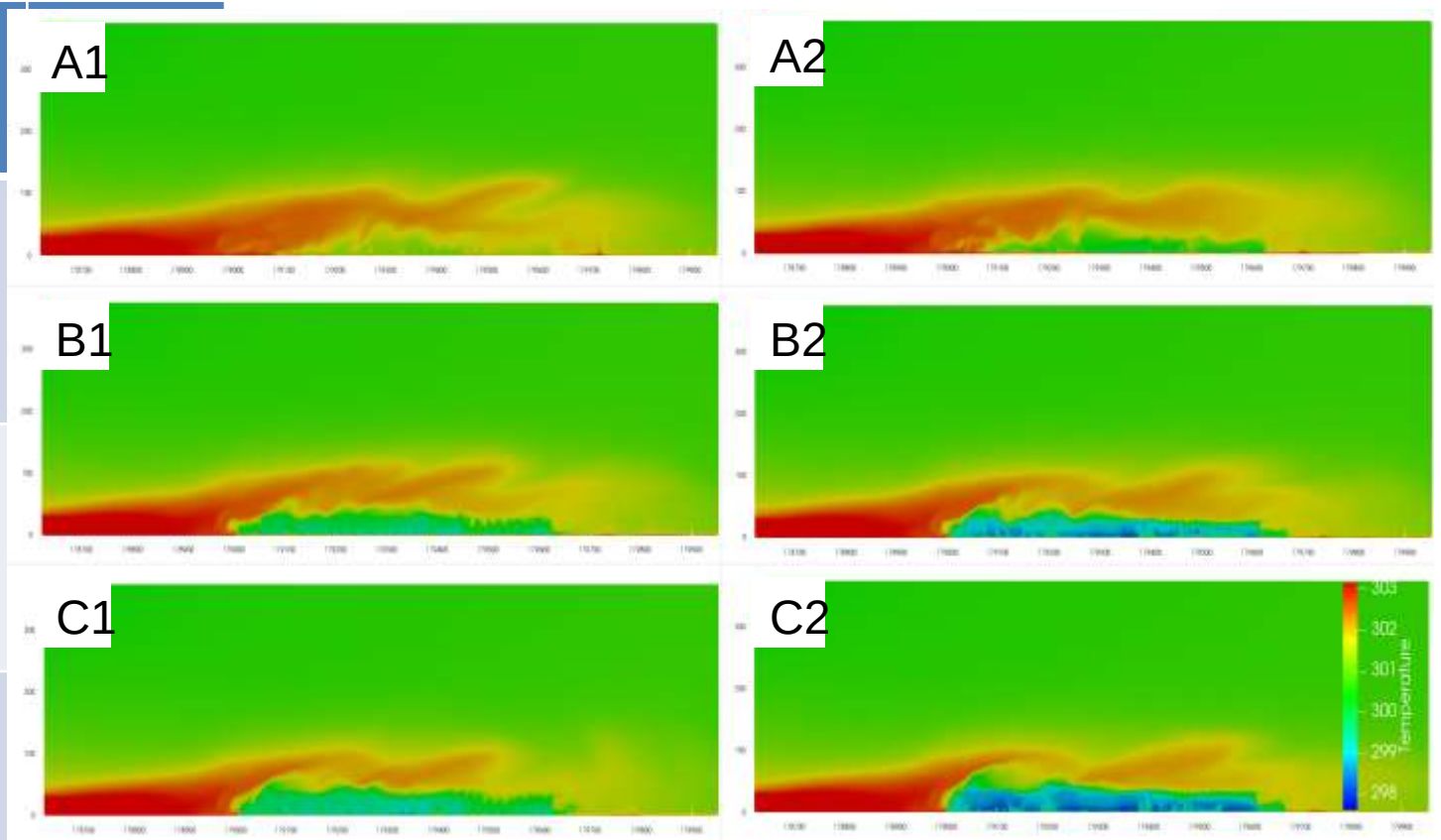
Temperature in the cross section along Queens' Gate

Parameters for Trees

Type	Height (m)	Crown (m)	LAD (m^2/m^3)
A1	10	9	0.5
A2			
B1	15	12	1
B2			
C1	20	12	1
C2			

With space between trees

No space between trees

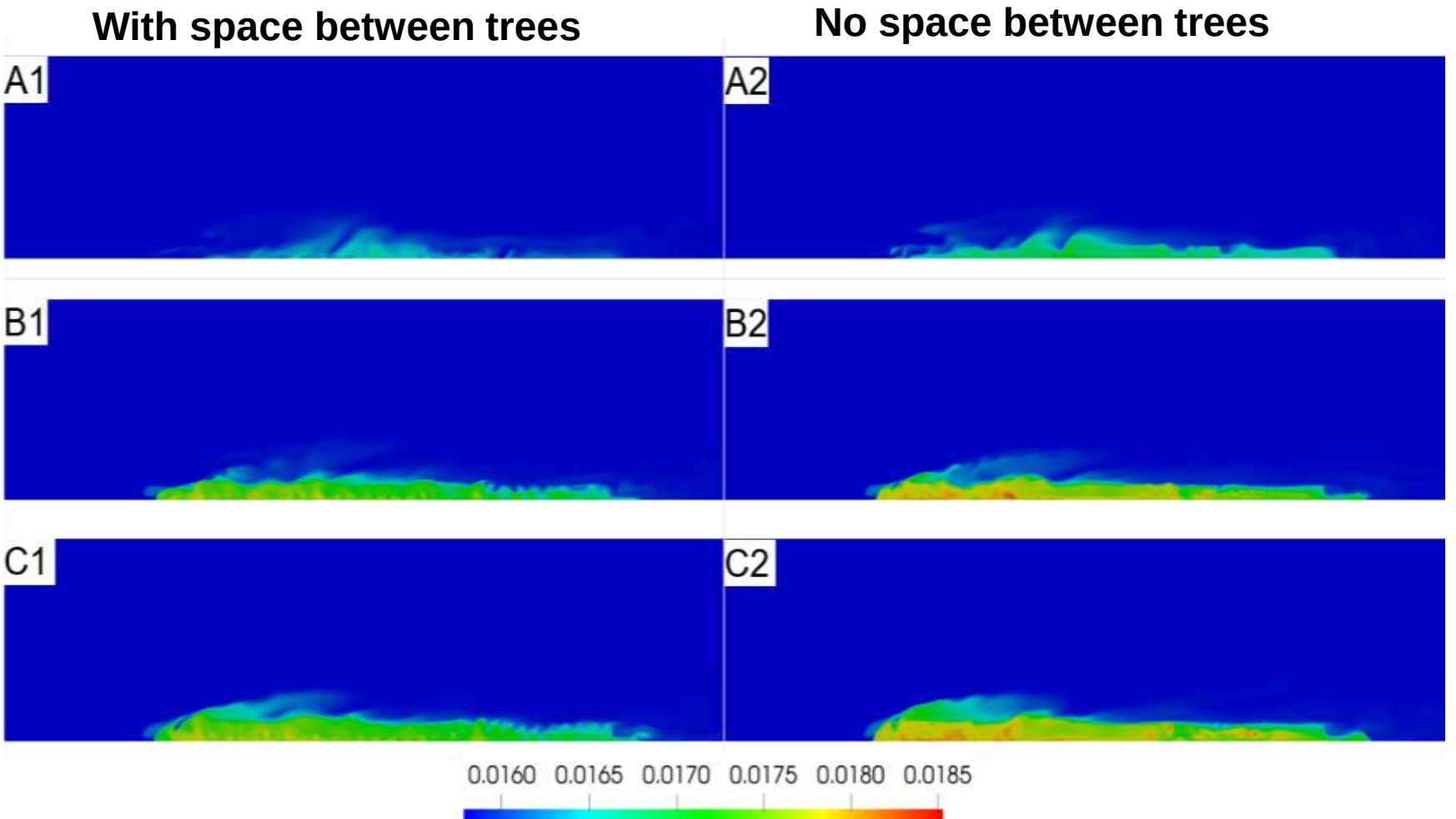


Thermal inversion layer

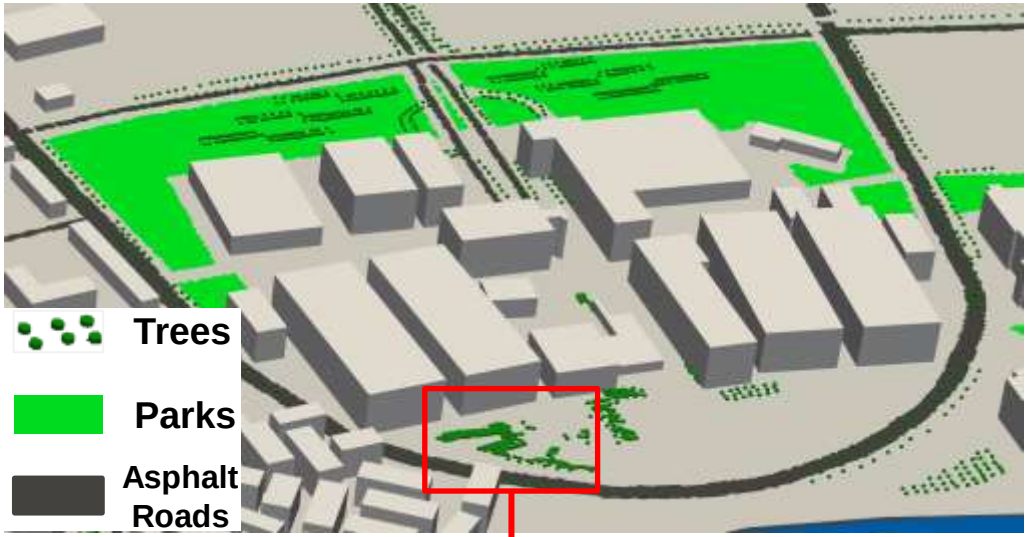
No space

Effect of tree species and distance on urban environment

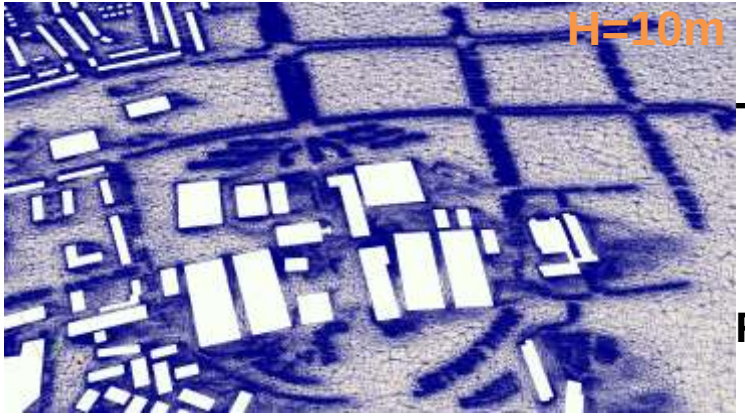
Specific humidity in the cross section along Queens' Gate



Coupled simulation with the tree and land surface processes



Domain, Mesh and Timestep



Domain

4.22 km X 4.26 Km X 250 m

Mesh

Length: 1m ~ 80m
Cells: 30,587,132
Points: 5,742,694
Adaptive Mesh:
Velocity 0.2 m/s
Temperature 0.3°C

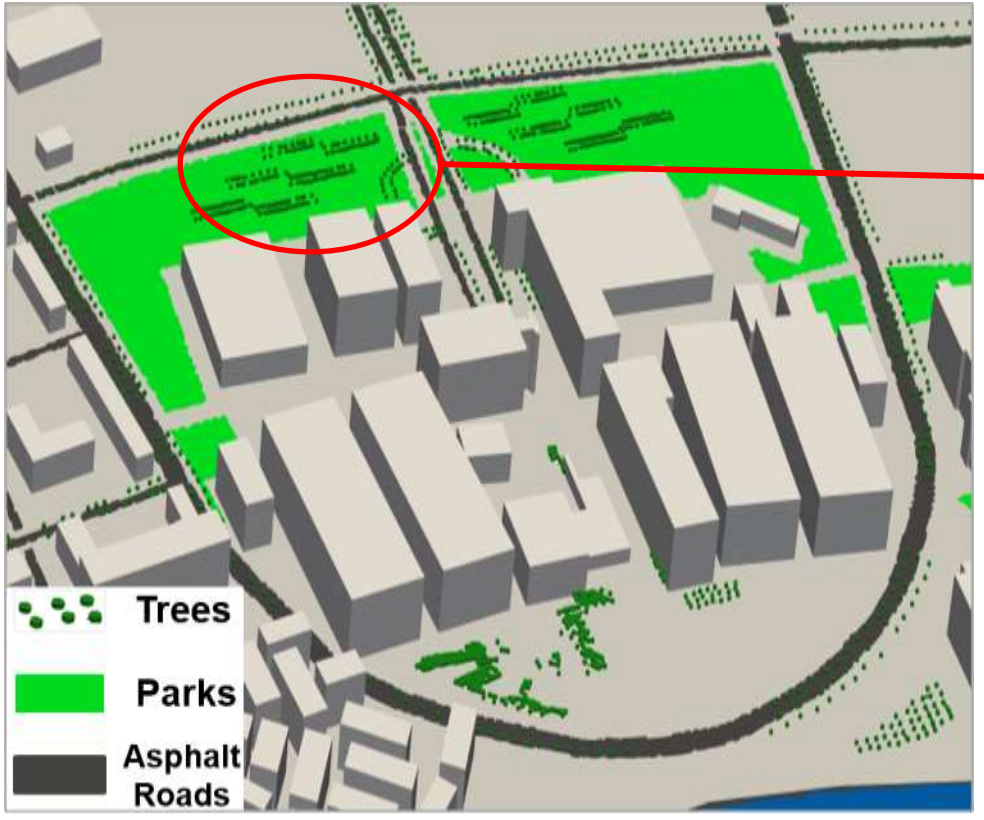
Timestep

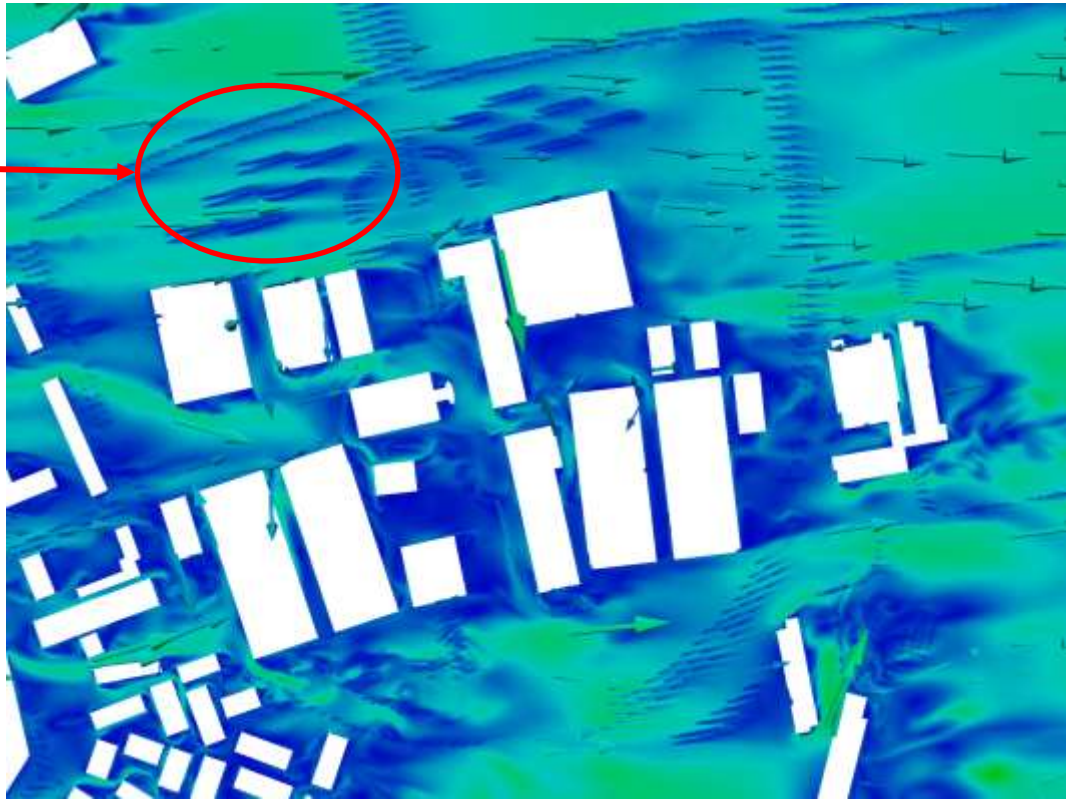
Adaptive timestep (≈0.6s)
CFL: 10

Run Time:

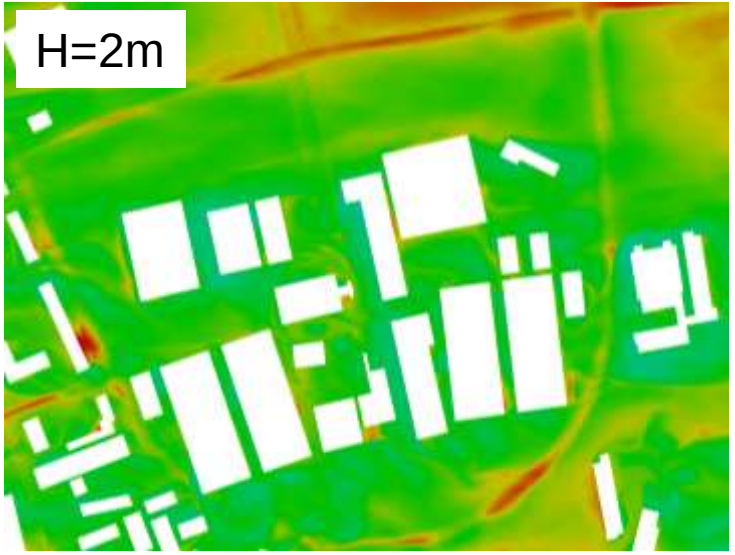
parallel run with 64 cores
1min simulation needs 18h

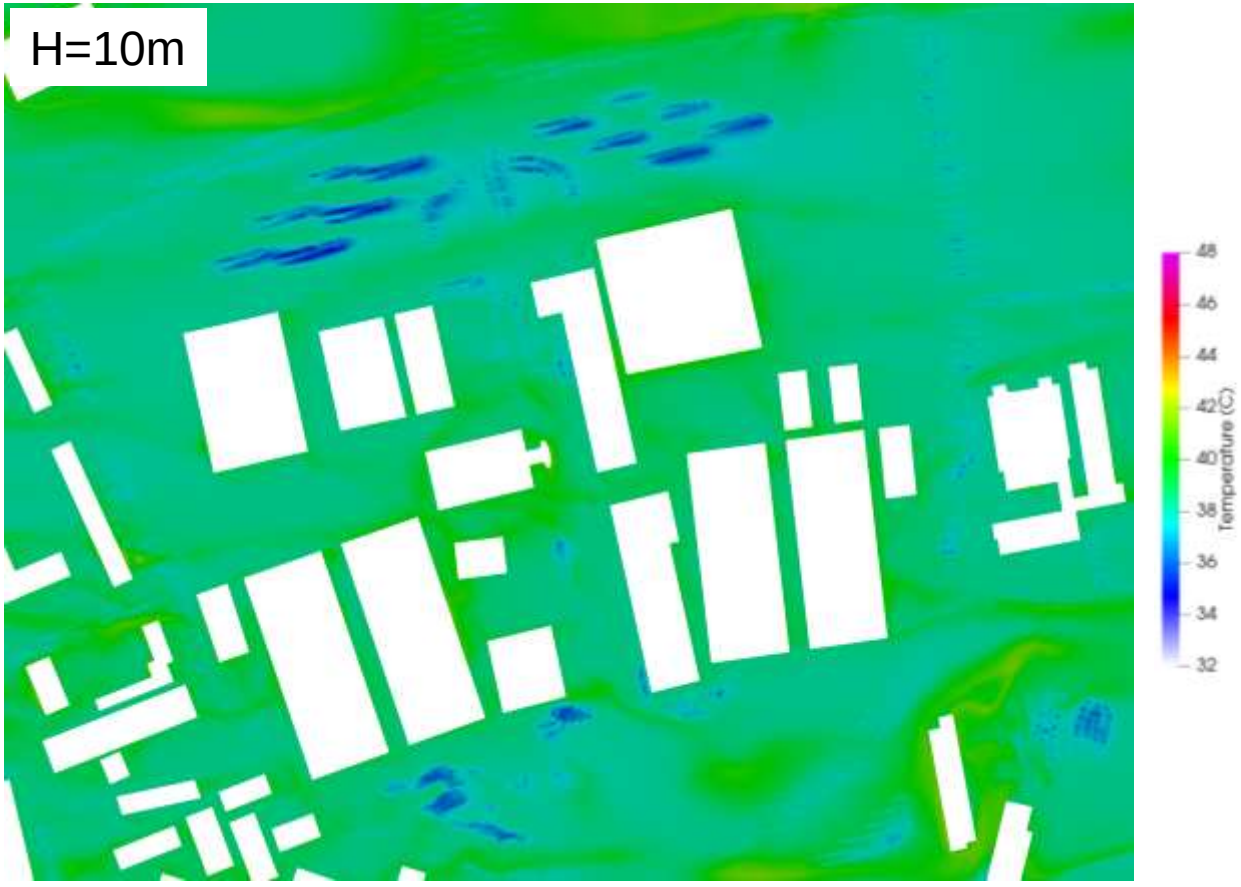
Velocity (H=10m)





Temperature

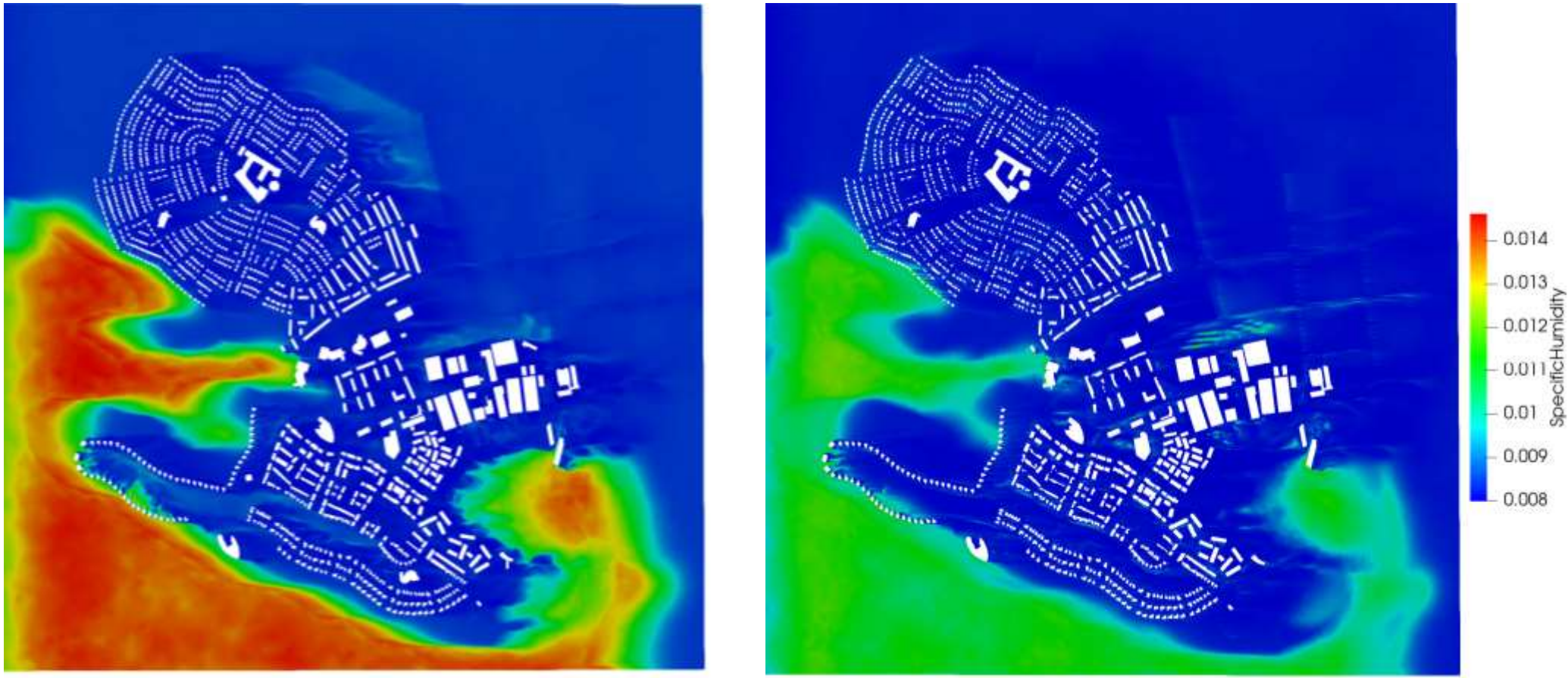




Humidity

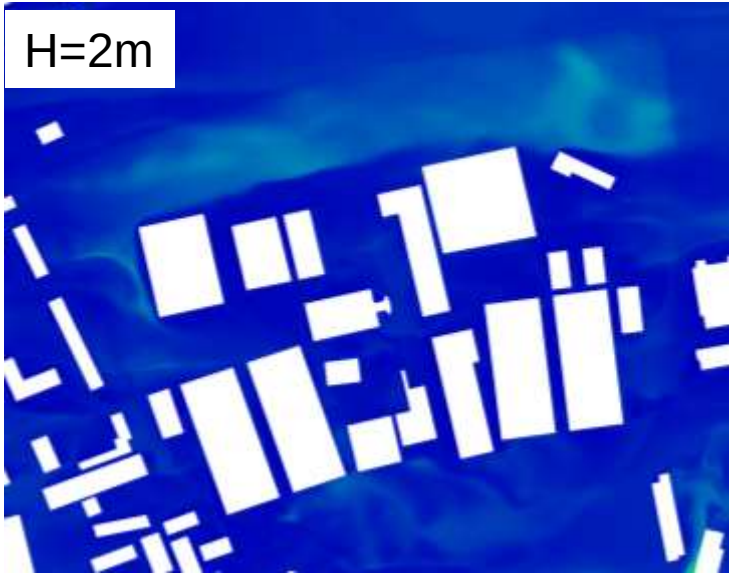
H=2.0m

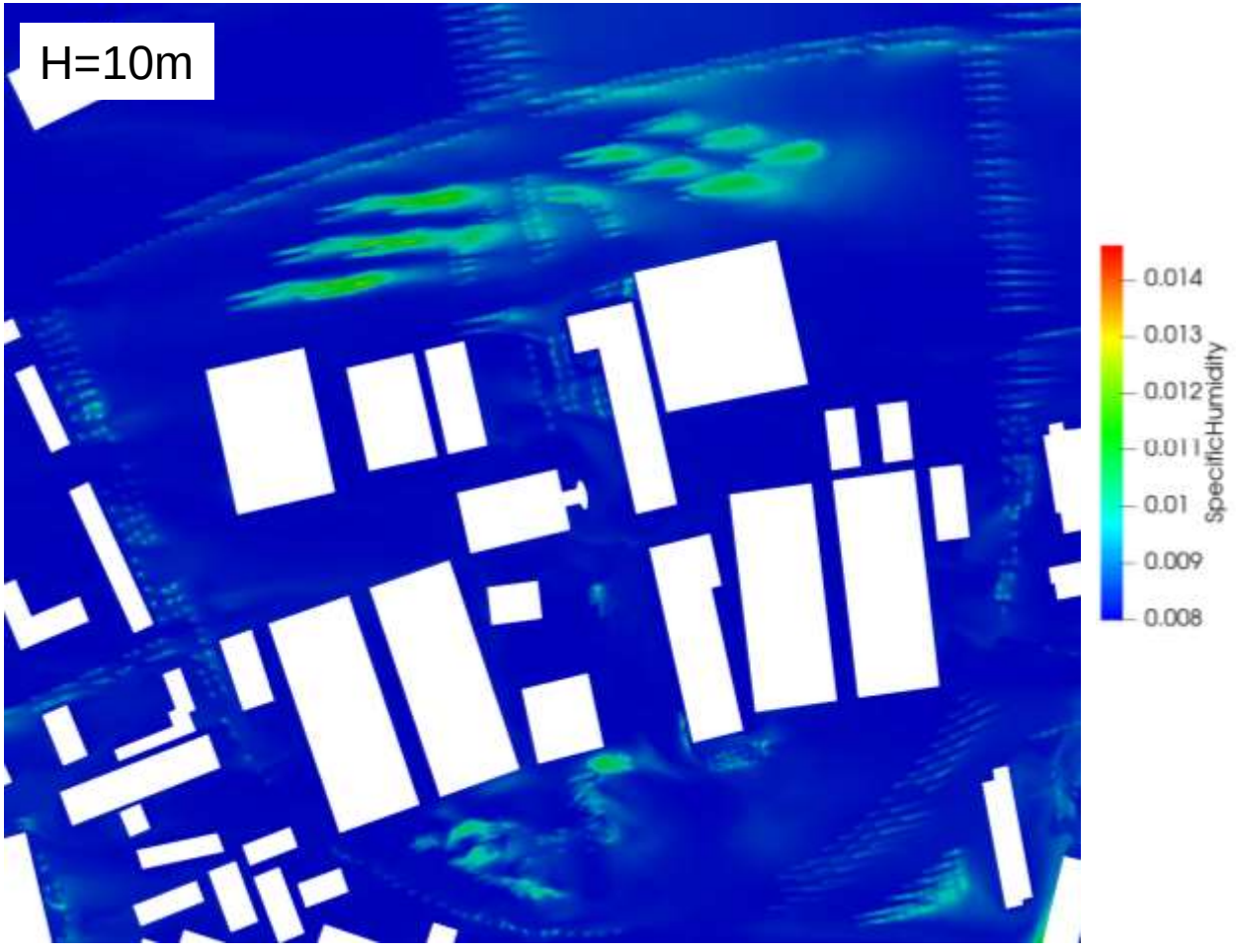
H=10.0m



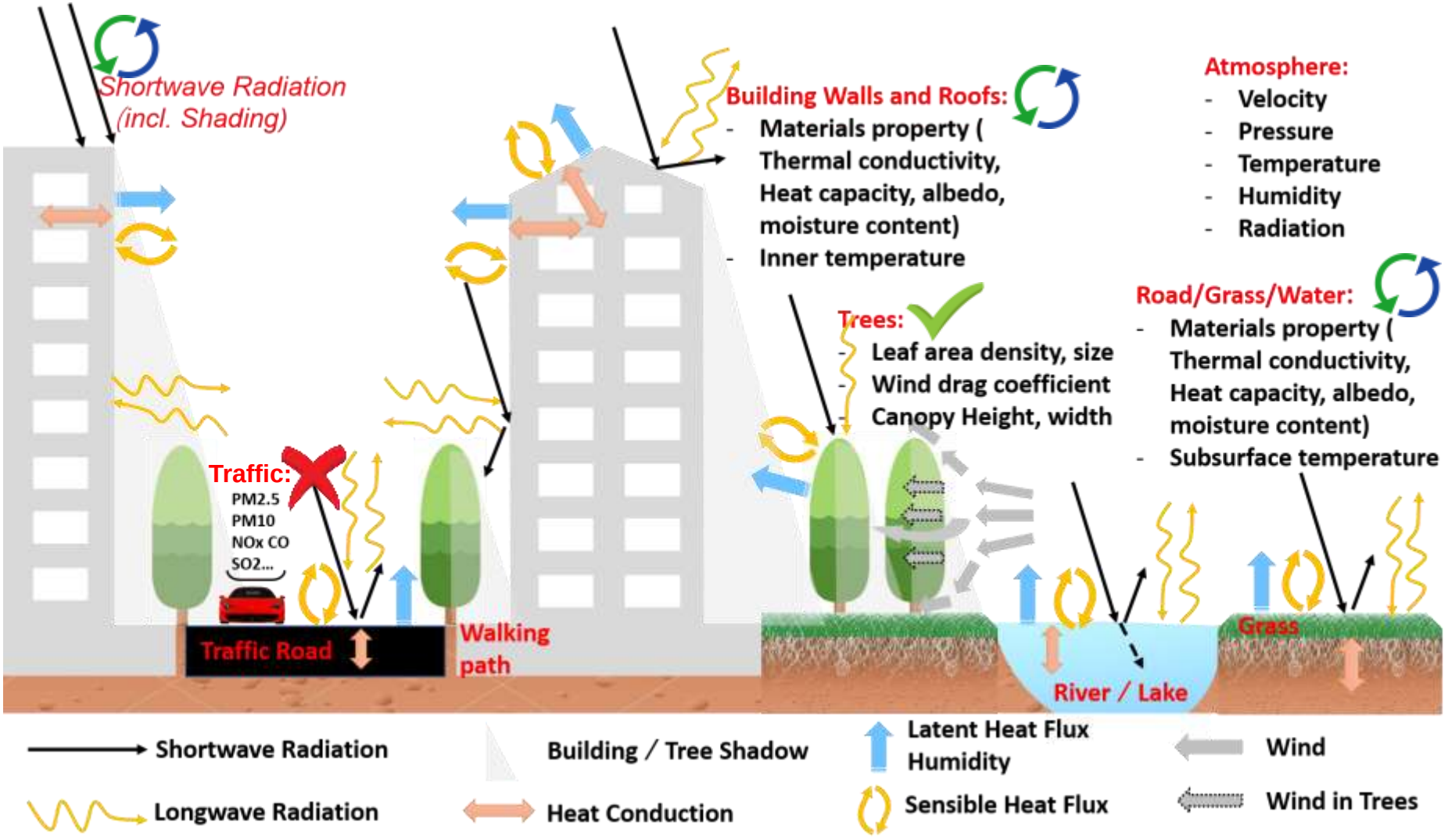
Humidity


Trees
Parks
Asphalt Roads

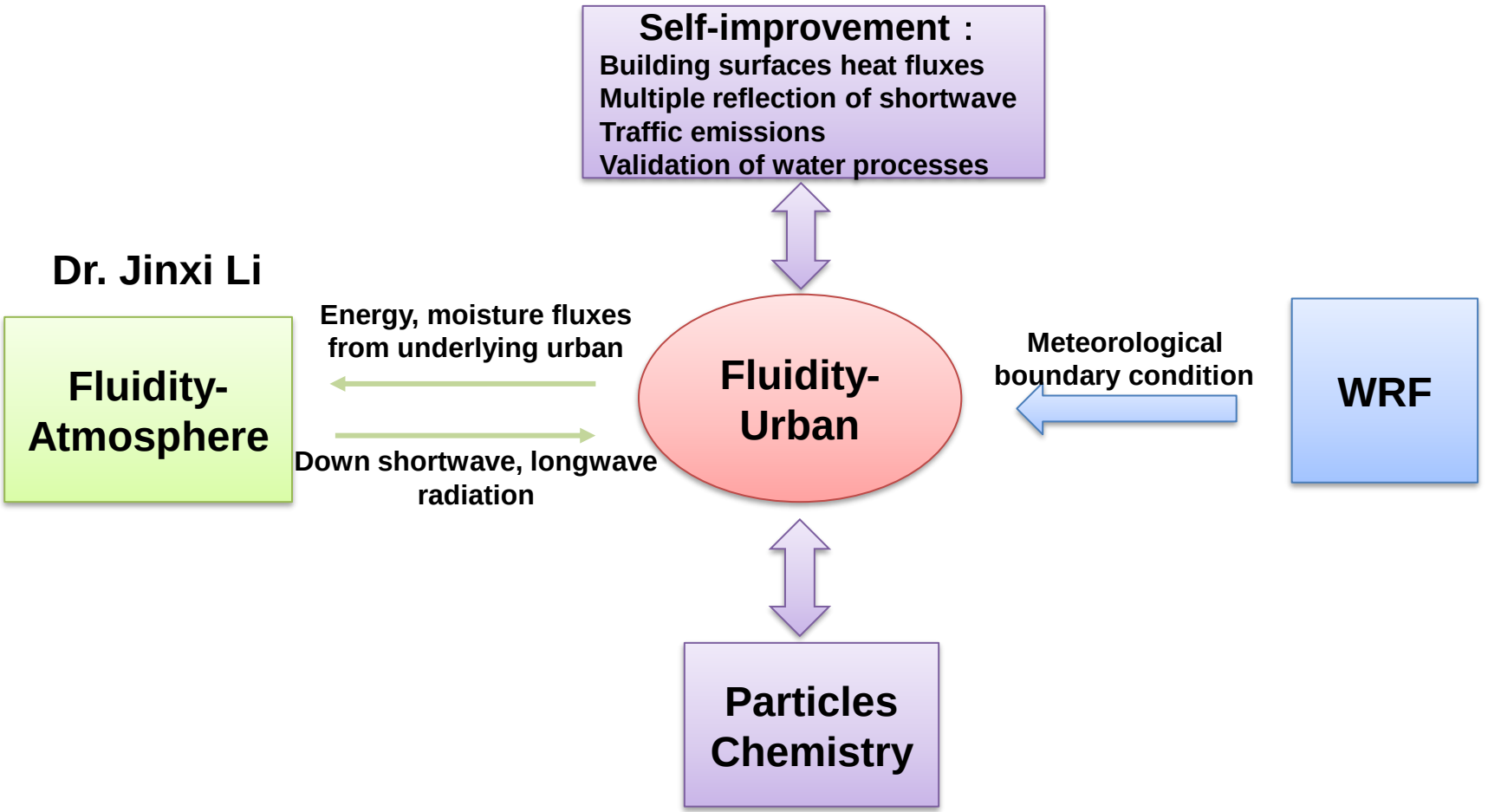

H=2m


H=10m
0.014
0.013
0.012
0.011
0.01
0.009
0.008
SpecificHumidity

Summary: Processes in the development of Fluidity-Urban model



Future Work


Self-improvement：
Building surfaces heat fluxes
Multiple reflection of shortwave
Traffic emissions
Validation of water processes
Dr. Jinxi Li
Fluidity-Atmosphere
Energy, moisture fluxes from underlying urban
Down shortwave, longwave radiation
Fluidity-Urban
Meteorological boundary condition
WRF
Particles Chemistry