DEVELOPMENT OF A 1D CANOPY MODULE TO IMPROVE SURFACE PARAMETERIZATIONS

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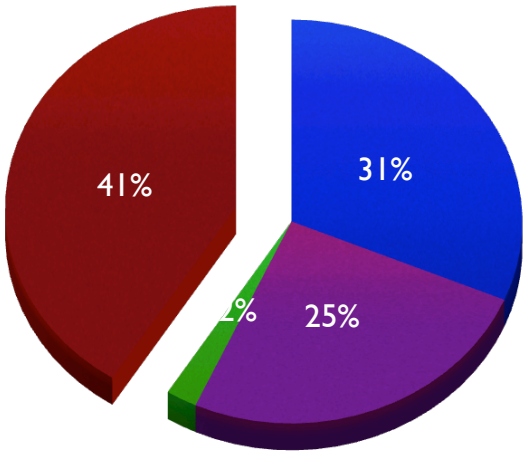
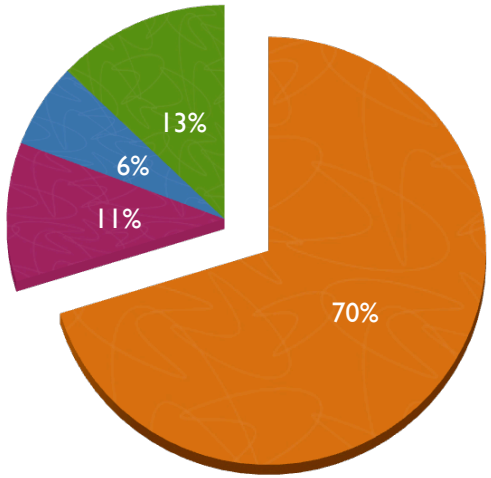
BUILDINGS, ENERGY USE & CLIMATE CHANGE





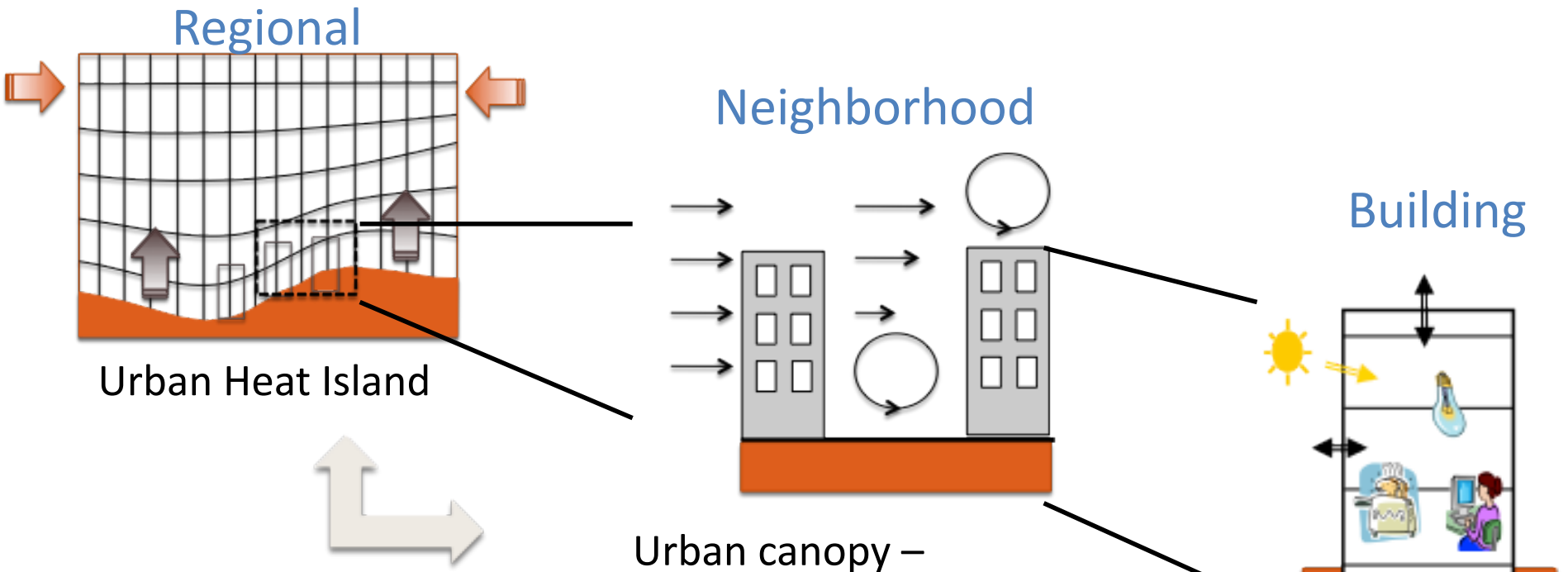
Energy consumption by sectors

- Transport
- Industries
- Other sectors
- Residential

Energy use inside buildings

- Heating/ Air conditioning
- Sanitary hot water
- Cooking
- Specific electricity (light, …)

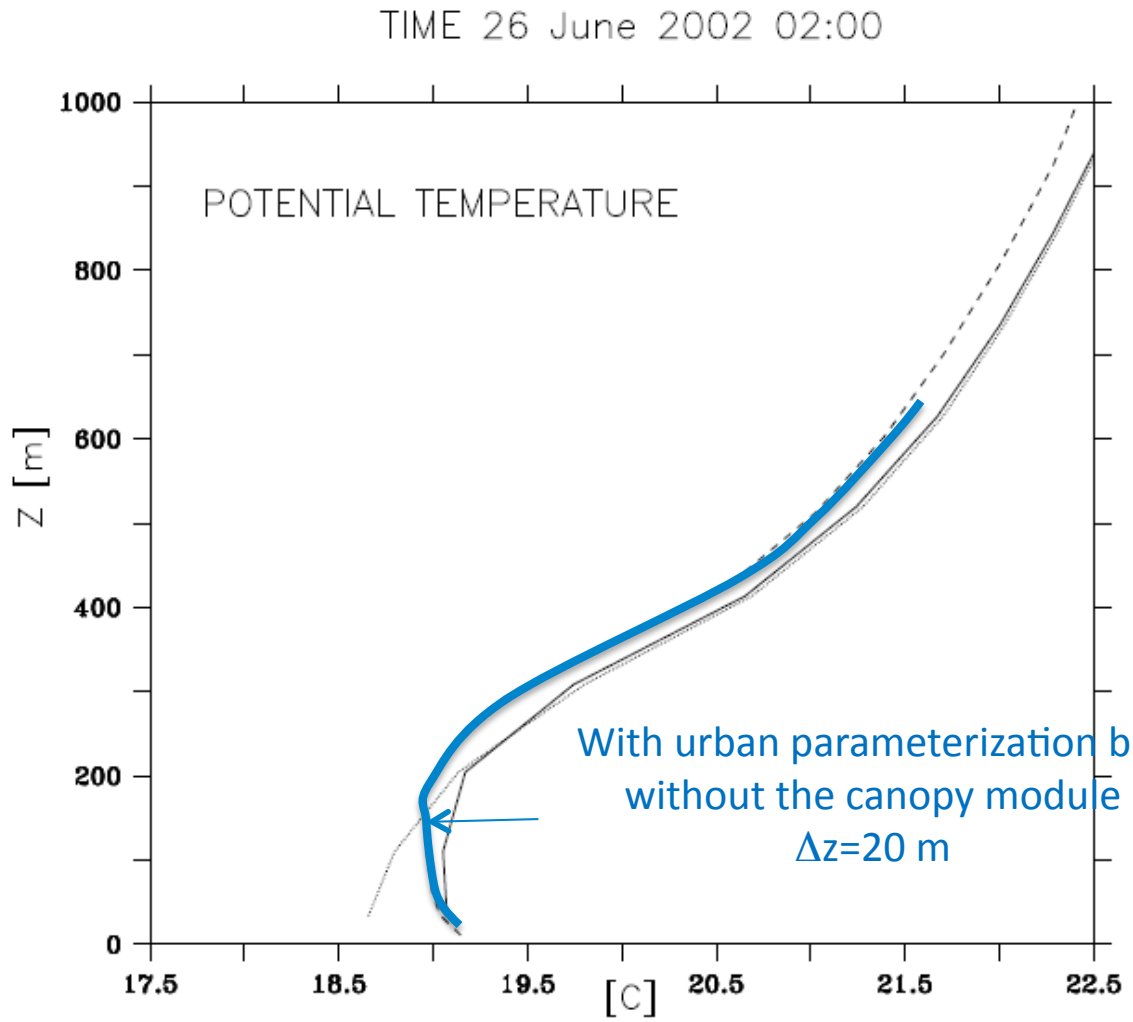
INTERACTIONS AT DIFFERENT SCALES



Mesoscale Model
FVM model (Clappier, 1996)
WRF model (Skamarock et al., 2005)

Microscale Model/Parameterizations
BEP-BEM (Martilli et al., 2002, Krpo et al., 2010, Salamanca et al., 2010)

WHY USE A CANOPY MODULE?



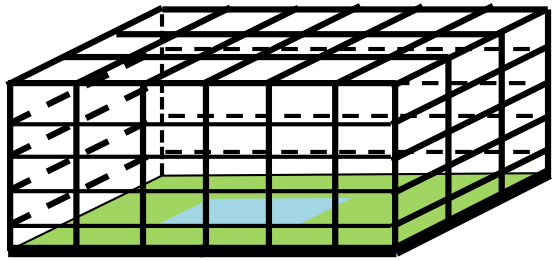
Use of a column module in the urban canopy model improves the simulations of mesoscale model with a low vertical resolution.

(Müller C., 2007)

THE CANOPY MODULE

MESOSCALE MODEL

WRF model (Skamarock et al., 2004)
FVM model (Clappier, 1996)



U – Wind speed
Θ– Potential temperature
F- Fluxes

$F_{U\ canopy}$, $F_{\theta\ canopy}$

U_{meso}, θ_{meso}

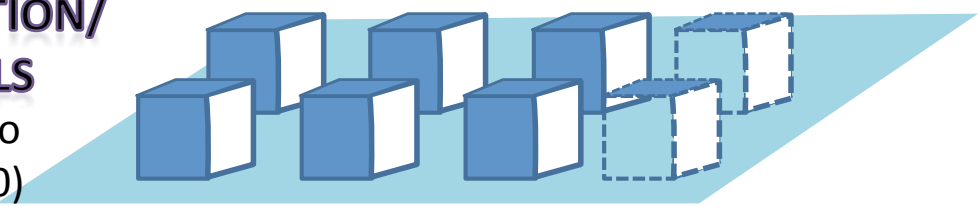
Canopy model

$F_{U\ surface}$, $F_{\theta\ surface}$

U_{canopy}, θ_{canopy}

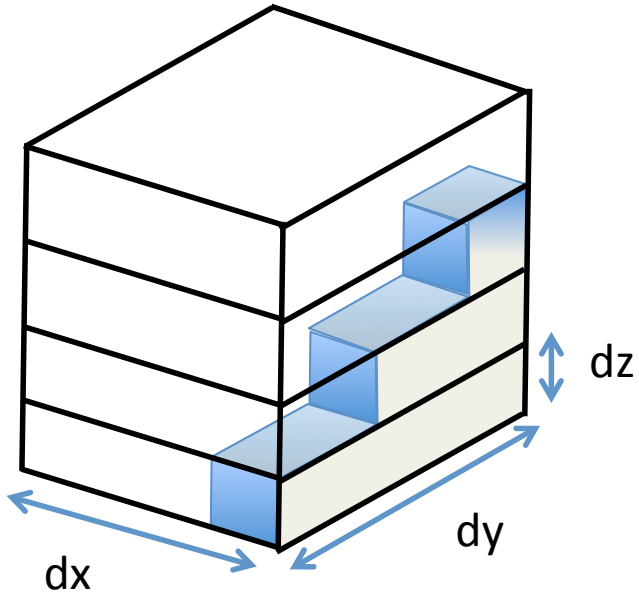
SURFACE PARAMETRIZATION/ MICRO SCALE MODELS

BEP-BEM (Martilli et al., 2002, Krpo et al., 2010, Salamanca et al., 2010)



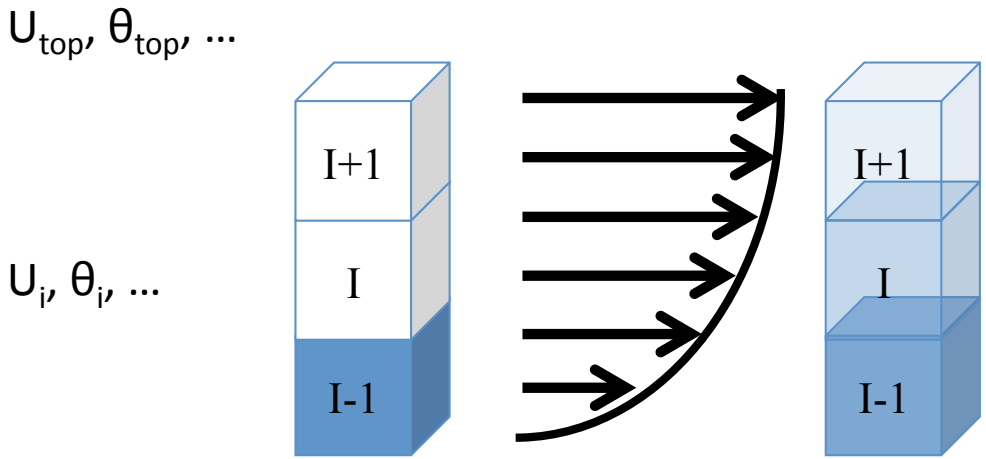
THE CANOPY MODULE

- 1-D column
  - Forced at the top by a mesoscale meteorological model



- Obstacles Representation
  - Surface porosities and volume porosities

DIFFUSION IN THE CANOPY

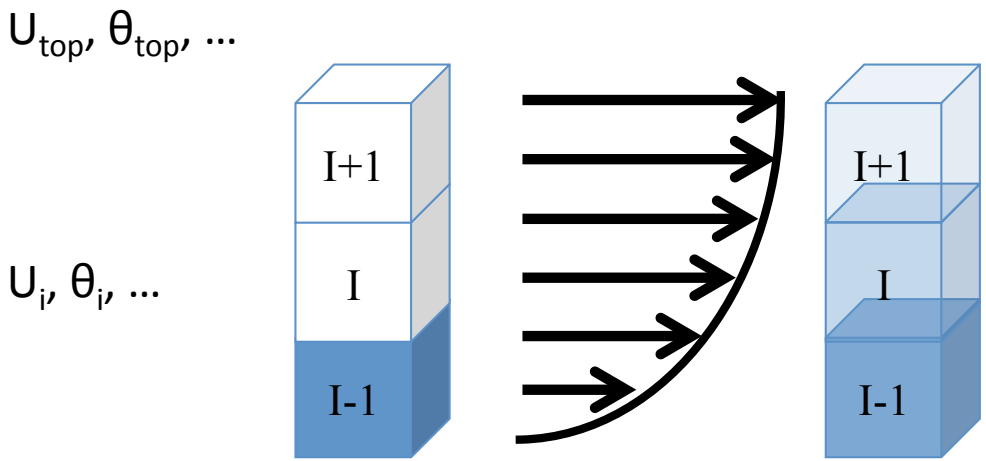


'ϕ' – volume porosities
'φ' – surface porosities
'*F*' – source fluxes

$$\frac{\partial U}{\partial t} = \frac{\partial}{dz}\left(\mu_t \frac{\partial U}{\partial z}\right) + F_u$$

'μ_d' – diffusion coefficient
'*U*' – wind speed (ms^{-1})
'F_u' – Source fluxes

DIFFUSION IN THE CANOPY



'ϕ' – volume porosities
'φ' – surface porosities
'*F*' – source fluxes

$$U_I^{t+1} = U_I^t + \Delta t \frac{\varphi_i}{\phi_I} \mu_t \frac{U_{I-1} - U_I}{\Delta z} + \Delta t \frac{\varphi_{i+1}}{\phi_I} \mu_t \frac{U_I - U_{I+1}}{\Delta z} + F_u$$

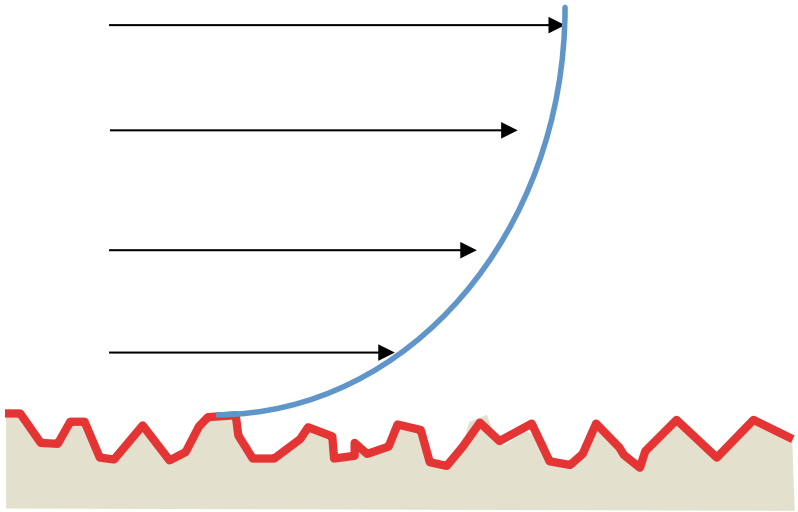
'μ_d' – diffusion coefficient
'*U*' – wind speed (ms^{-1})
'F_u' – Source fluxes

INTERACTION IN THE CANOPY– WITHOUT OBSTACLES

– Horizontal surfaces

Momentum fluxes $$\vec{F}_U^H = \frac{\left|U^{hor}\right|\vec{U}k^2}{\left(\ln\left(\frac{z}{z_0}\right)\right)^2}$$

Heat fluxes $$F_\theta^H = \frac{U(\theta-\theta_{surf})k^2}{\left(\ln\left(\frac{z}{z_0}\right)\right)^2}$$



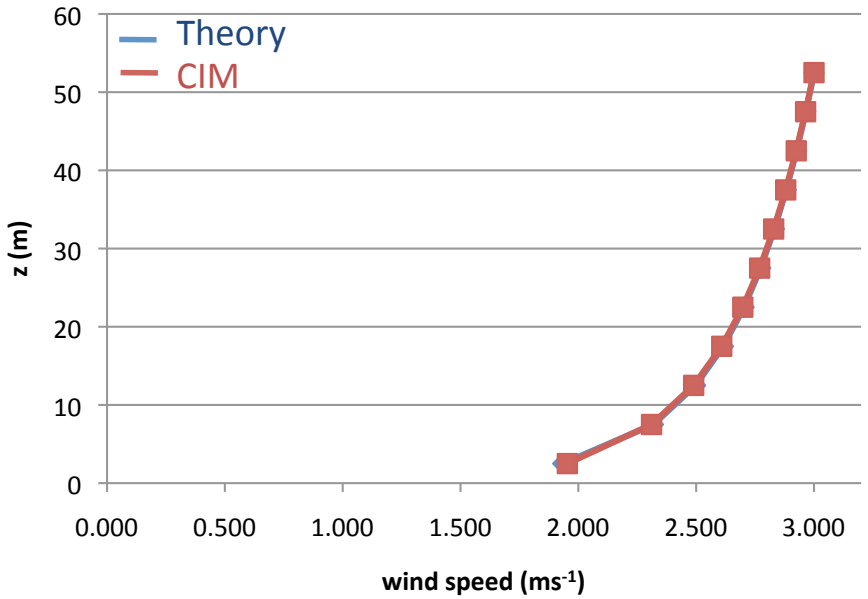
TURBULENT KINETIC ENERGY

$$\frac{\partial E_k}{\partial t} = \left(\mu_t \frac{\partial E_k}{\partial z}\right) + \mu_t \left(\frac{\partial U}{\partial z}\right)^2 - \frac{\mu_t}{\Pr} \frac{g}{\vartheta}\left(\frac{\partial \vartheta}{\partial z}\right) - C_\varepsilon \frac{E_k^{\frac{3}{2}}}{l}$$

'E_k' – T.K.E
'g' – acc. due to gravity
'ϑ' – potential temperature
'Pr' – Prandtl number

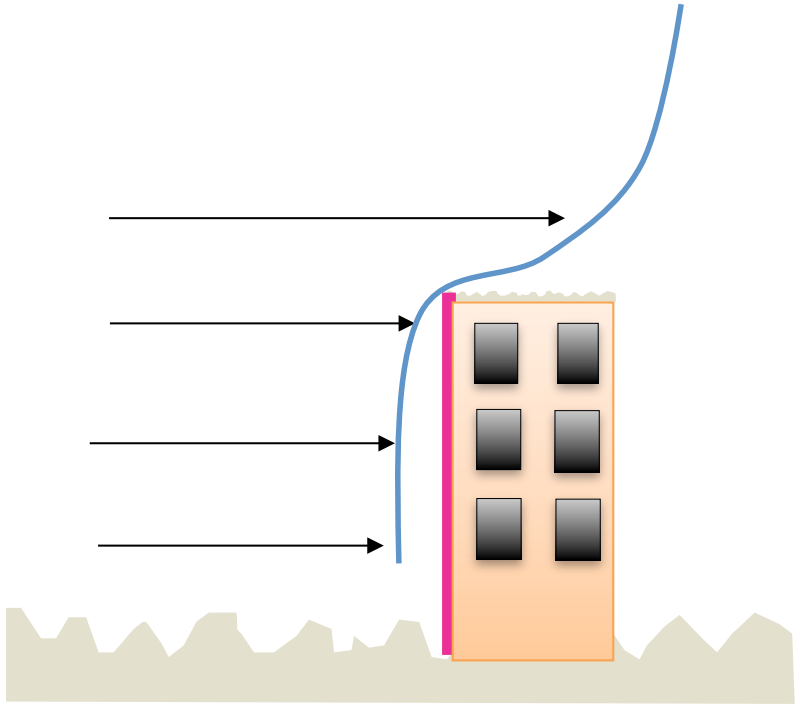
Diffusion | Mechanical Production | Buoyancy | Dissipation

$$\mu_t = C_\mu \sqrt{E} l$$



Wind speed profile with a logarithmic law

INTERACTION IN THE CANOPY– WITH OBSTACLES



- Vertical surfaces

Momentum fluxes $$\vec{F}_U^V = C_{drag} \left| U^{hor} \right| \vec{U}$$

Heat fluxes $$F_\theta^V = \frac{\eta_x}{2C_p}(\theta - \theta_{surf}) - \frac{\eta_y}{2C_p}(\theta - \theta_{surf})$$

'η' – constant proportional to wind speed
'Cp' – Heat capacity at constant pressure

WITH OBSTACLES

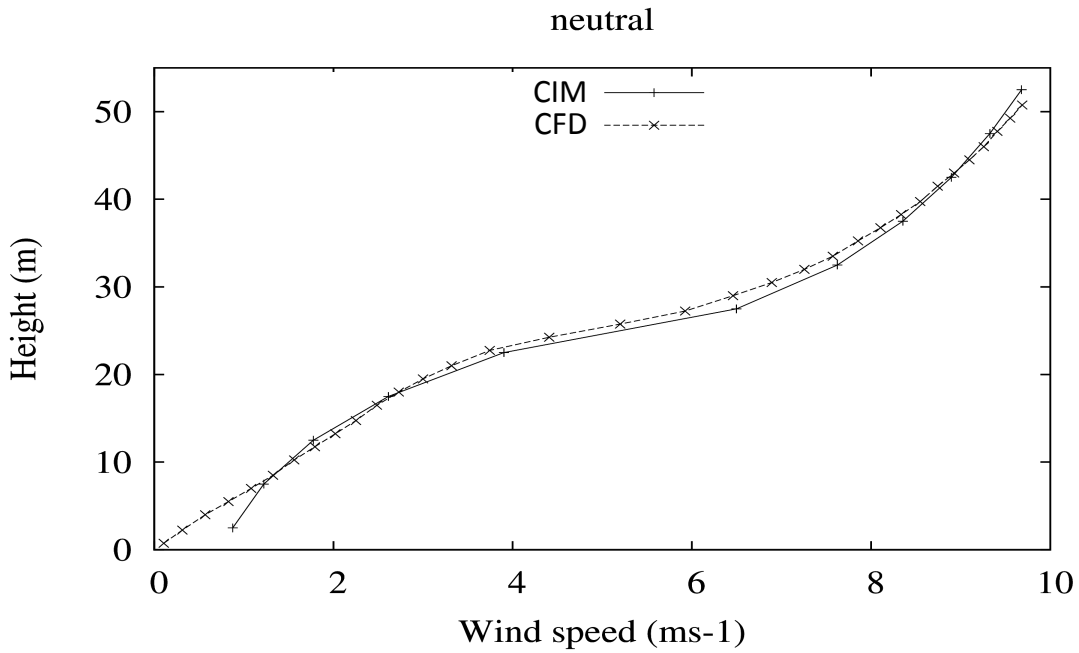
Presence of obstacles modifies:
-mixing length

$$l = z - d$$

$$d = h(1-\phi)^{0.13}$$

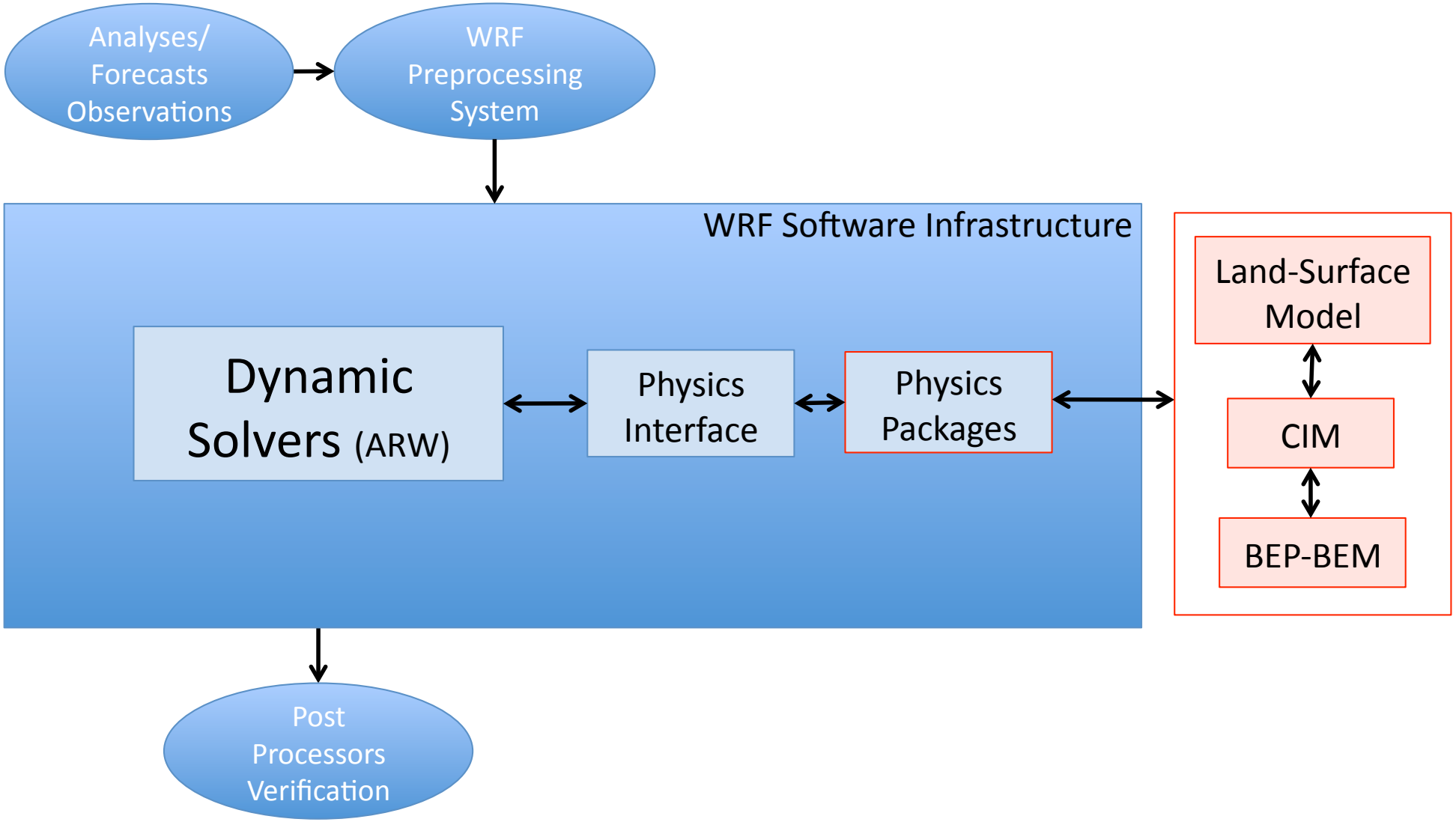
Where'*l*' – mixing length
'*z*' - height
'd' – displacement height
'*h*' – building height
'*vcp'* – volume porosity

From Santiago & Martilli, 2010

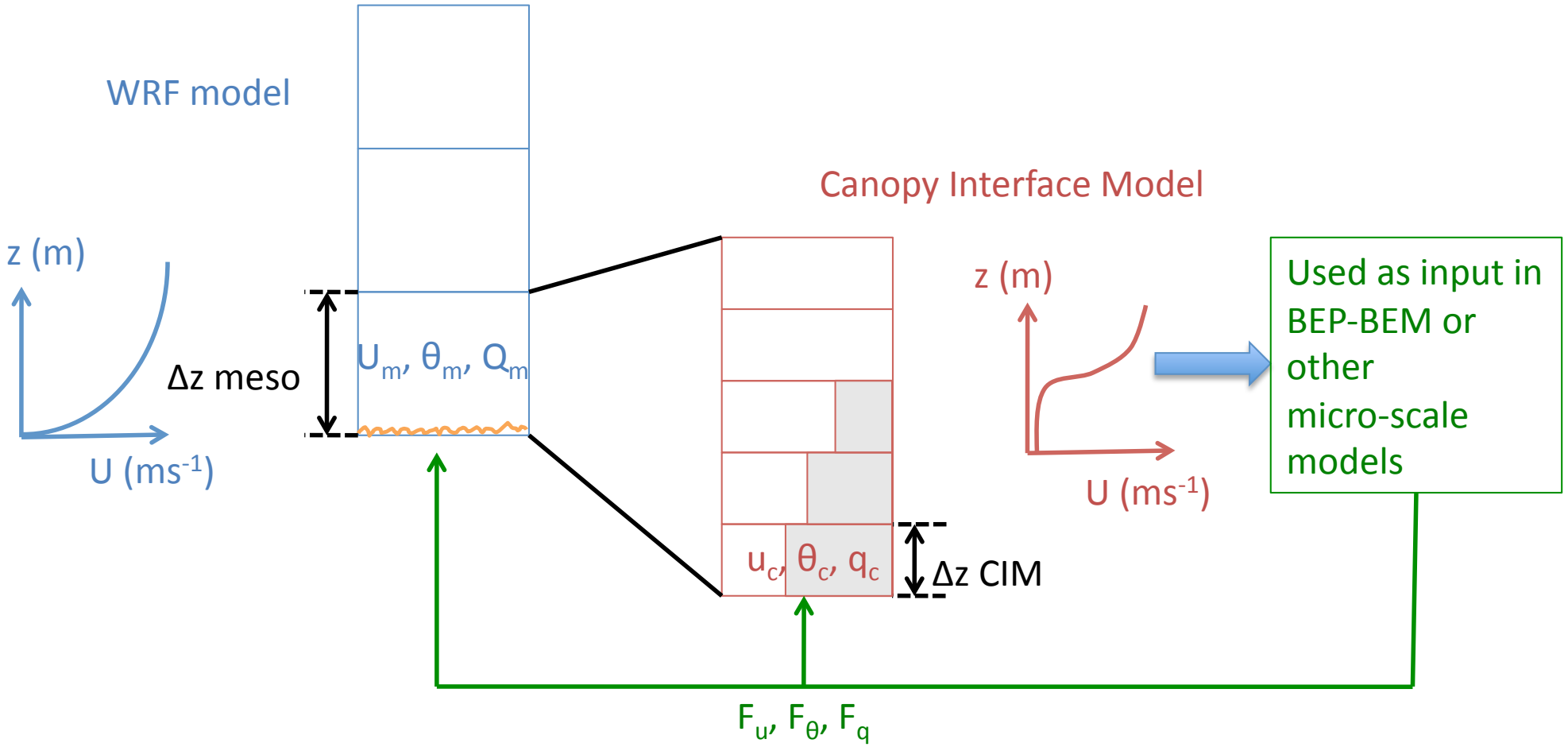


Wind speed profile with obstacles of 25m high in a domain of 1km*1km and 50m high

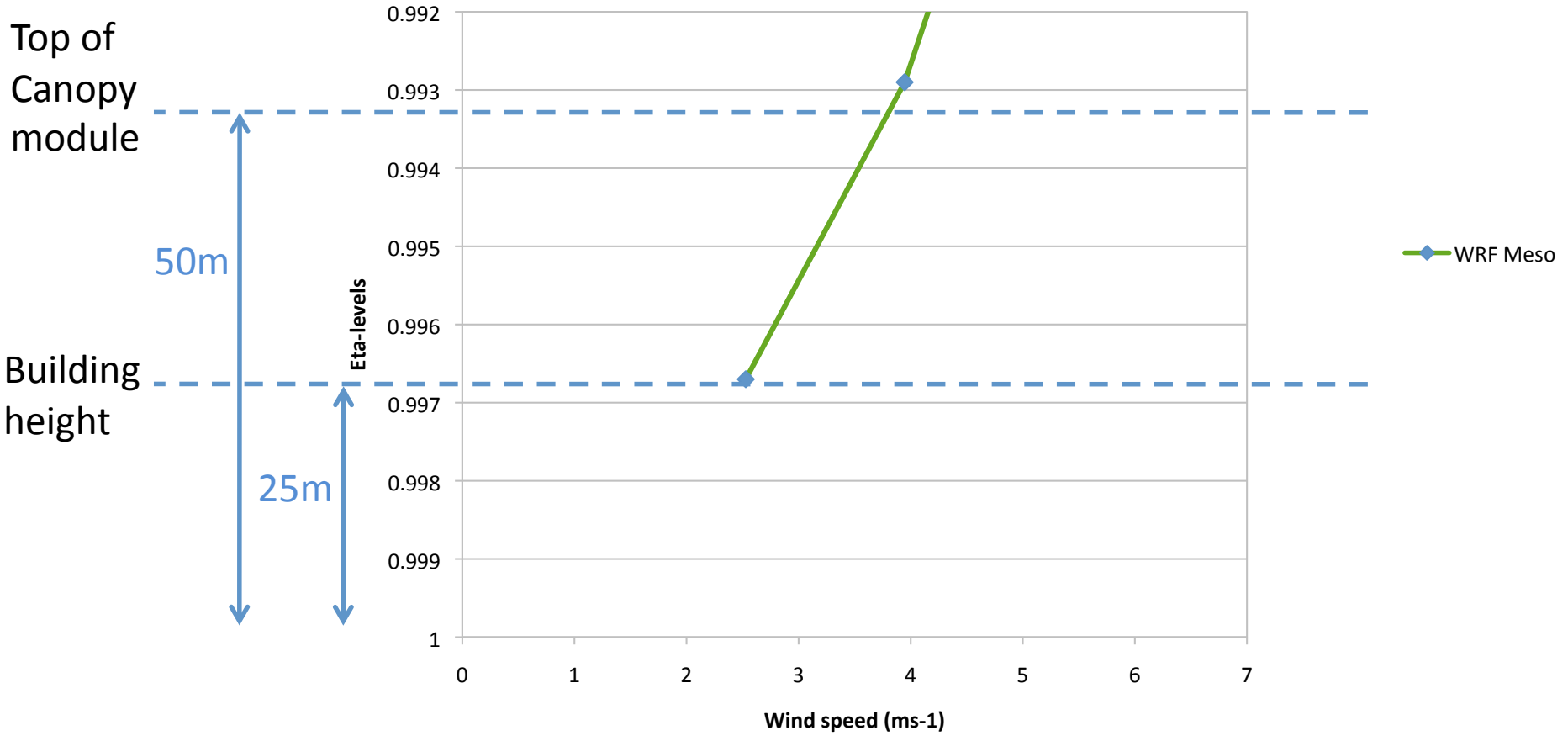
WRF – COUPLING TO CIM (1)



WRF – COUPLING TO CIM (2)

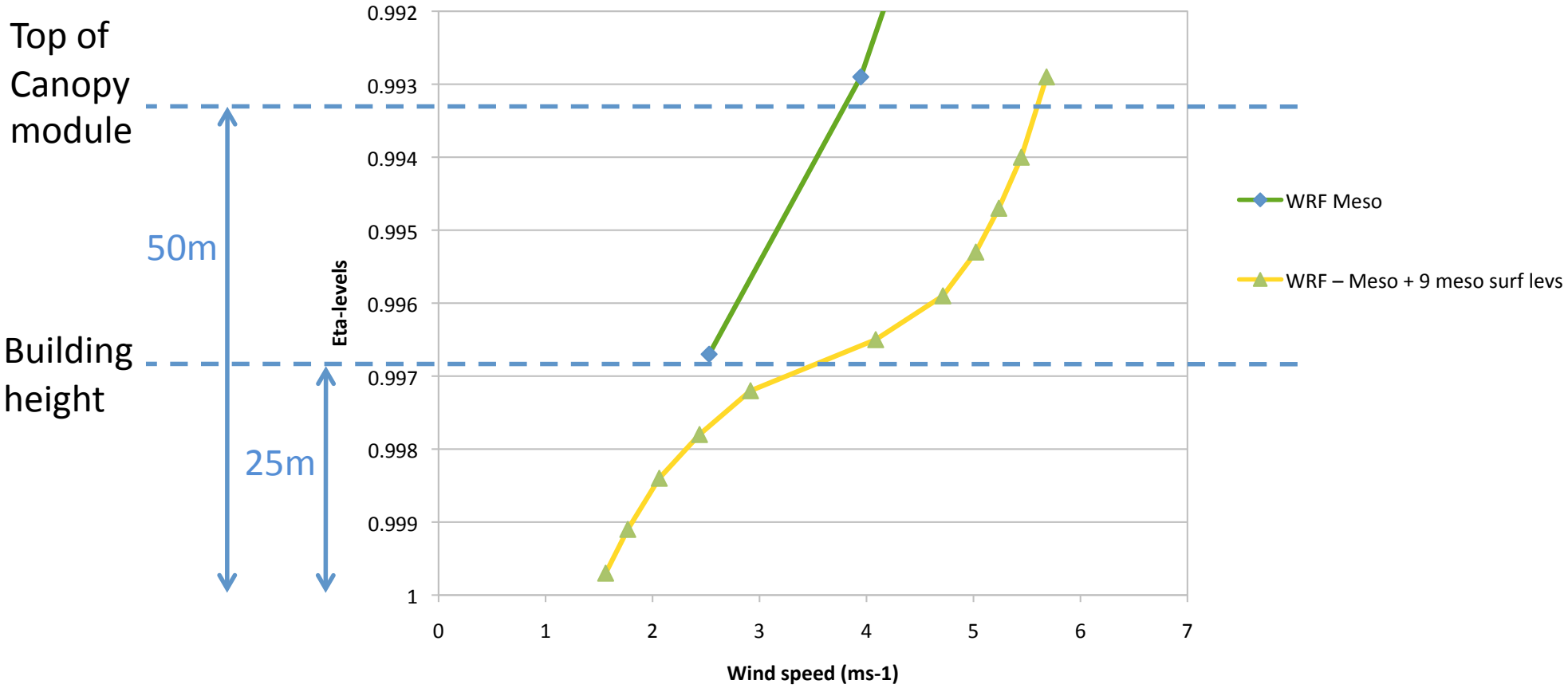


PRELIMINARY RESULTS: SENSIBILITY TESTS



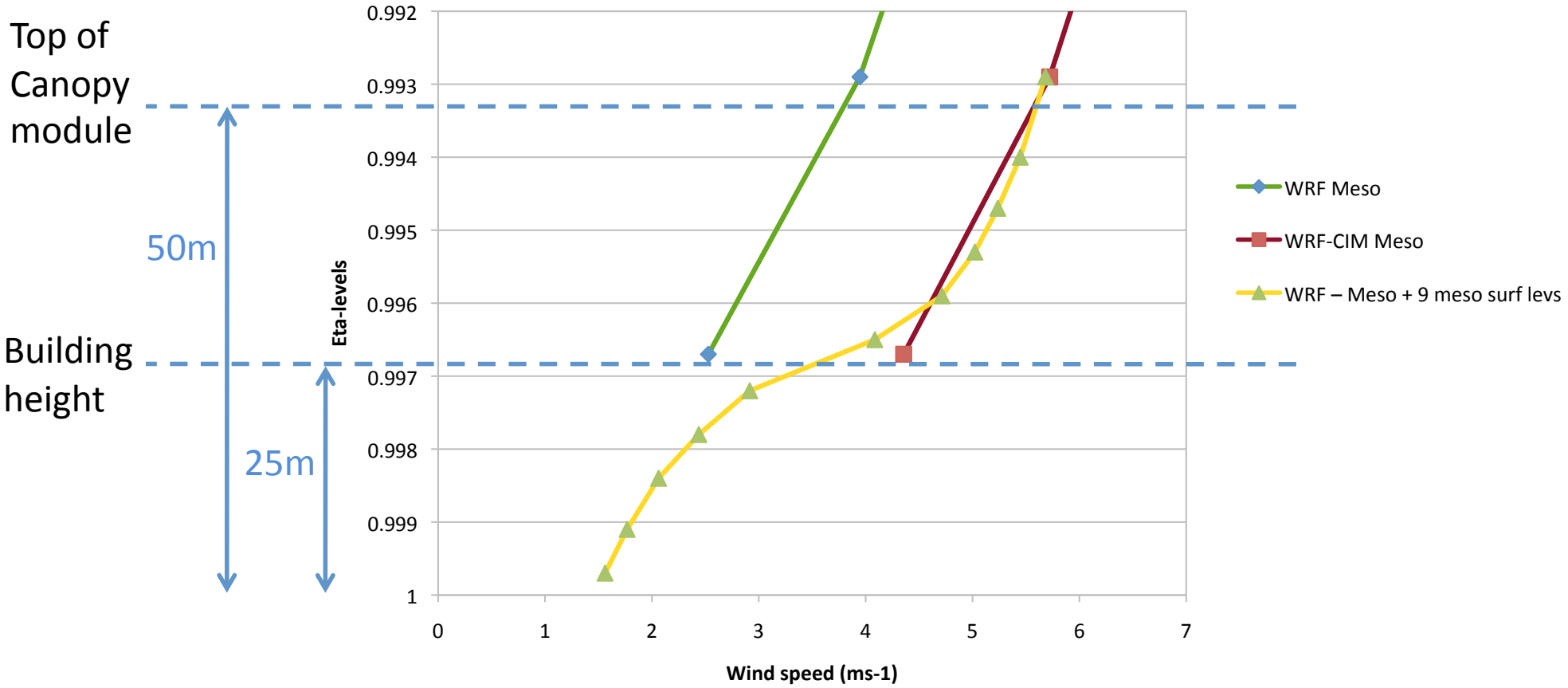
Horizontal wind speed from WRF

PRELIMINARY RESULTS: SENSIBILITY TESTS



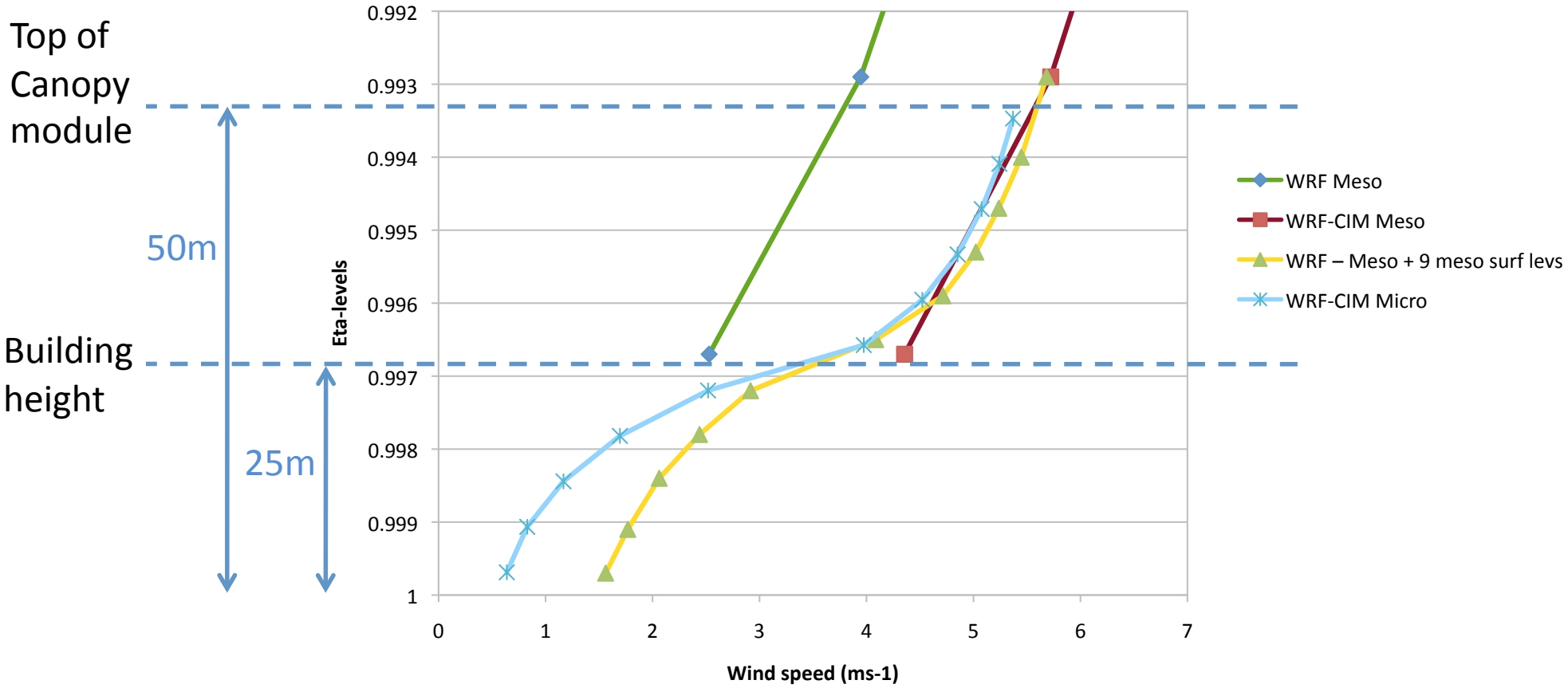
Horizontal wind speed from WRF

PRELIMINARY RESULTS: SENSIBILITY TESTS



Horizontal wind speed from WRF and WRF+CIM

PRELIMINARY RESULTS: SENSIBILITY TESTS



Horizontal wind speed from WRF and WRF+CIM

CONCLUSIONS & PERSPECTIVES

- CIM 1D – diffusion model
- Interface to improve calculation of meteorological variables in the surface layer
- Capacity to reduce:
  - vertical resolution
  - in computational time
- Improvement in the reproduction of the urban boundary layer
- Used in mesoscale model but can be applied to global models

THANK YOU FOR YOUR ATTENTION

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