# Development of a new 1D urban canopy model: coherences between surface parameterizations

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## Canopy Interface Model (CIM) – A need for theoritical coherence

A 1-D Canopy Interface Model (CIM) was developed in order to simulate the effect of urban obstacles on the atmosphere in the boundary layer (Mauree, 2014). The model solves the Navier-Stokes equations on a high-resolved gridded vertical column. Past theories were implemented one by one with the objective to test their relative coherences. The final proposition guarantees the coherence in any atmospheric stability and terrain configuration with a modification of the scaling parameters.

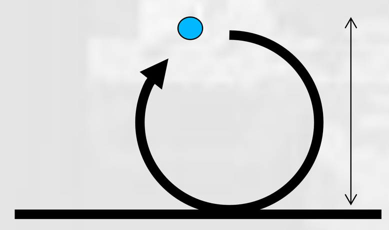
## Mixing turbulent coefficients and mixing length

Several parametrizations were proposed to simulate the turbulent mixing coefficients over plane surfaces and complexe surfaces. The most famous and used turbulence closure are:

- First-order turbulence closure : $\mu_t = \frac{ku^* l}{\varphi_m}$
- 1.5-order turbulence closure : $\mu_t = c_k\sqrt{e}l$

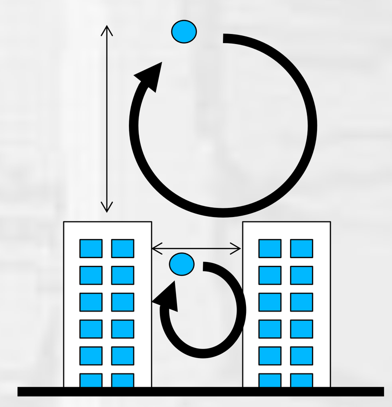
$l$ is the **mixing length**, that is understood as the **maximum distance that an air parcel may travel before to be in contact with a surface**

## Mixing length



Without obstacle the travel of an air parcel is limited by the distance to the surface : $l = z$

With urban obstacle the travel of an air parcel is limited by the distance to the maximum height of the building or the size of the canyons



## Without obstacles in neutral case

- $\varphi_m = 1$ and $l = z$
- Kinetic energy is constant with height : $e = cste$
- Energy production equaled to energy dissipation : $P = \mu_t\left(\frac{\partial U}{\partial z}\right)^2 = \varepsilon = c_\varepsilon{}^* \frac{e^{\frac{3}{2}}}{l}$

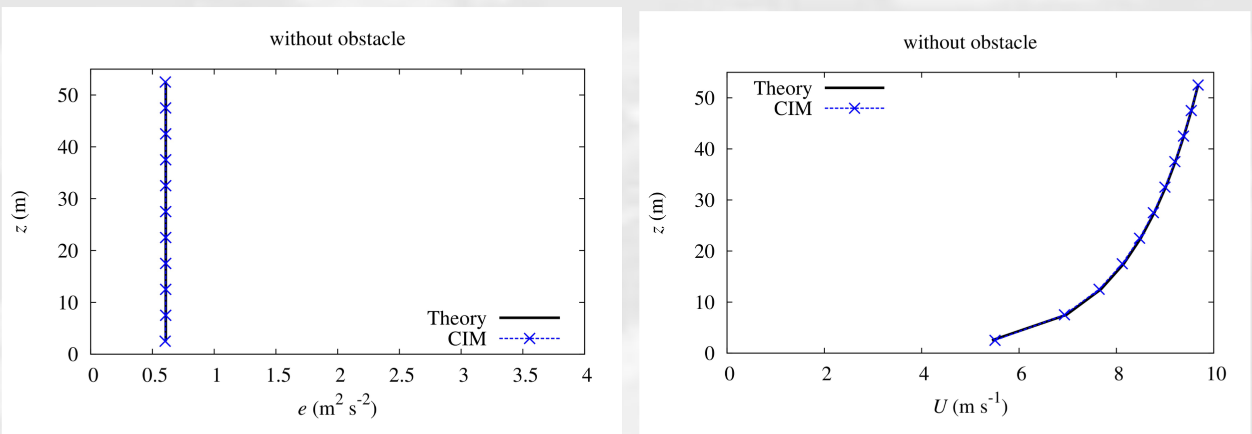



*Figure 1. Comparison of the wind U (in m/s) and e (in m² /s²) profiles computed using the analytical solution from the Prandtl surface-layer theory and CIM.*

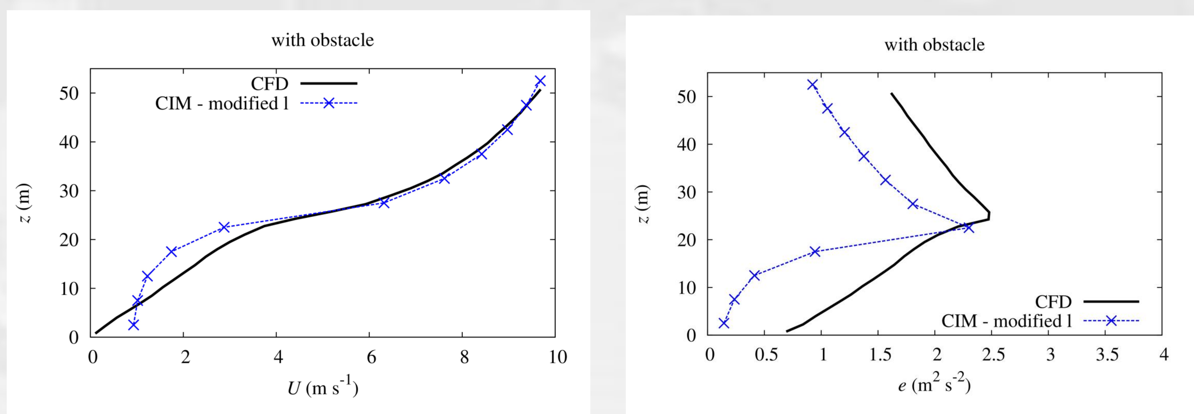
## Same mixing length for dissipation

but a new scaling constant $c_\varepsilon{}^*$. Most important thing: keep the scale between production and dissipation. Give a value to $c_\varepsilon{}^*$ fixes the value of $c_k$. With $c_\varepsilon{}^* = 1$, $c_k = k^{\frac{4}{3}}$

## Implementation of urban obstacles

CIM is based on a porosity formulation of the buildings. The mixing length is taken from Santiago and Martilli (2010): $l(i) = \max(h - d; z(i) - d)$ with d the displacement height taken as a function of h and the porosity $d = h(1-\varphi)^{\alpha}$.

*Figure 3. Comparison of the wind U (in m/s) and e (in m² /s²) profiles computed with a CFD (Thanks to J.L. Santiago and A. Martilli) and CIM. Cubic obstacles of 25 m. Porosity of 0.75.*




## Without obstacles in a stratified atmosphere

- $\varphi_m \neq 1$ and $l = z$
- Kinetic energy not constant with height any more: $e \neq cste$
- Energy production equaled to energy dissipation (Brouwers, 2007; Charuchittipan and Wilson, 2009) :

$$P\,(1 - R_{if}) = \mu_t\left(\frac{\partial U}{\partial z}\right)^2 (1 - R_{if}) = \varepsilon = c_\varepsilon{}^* \frac{e^{\frac{3}{2}}}{l}$$

- Consequence : a direct relation between $\varphi_m$ and $R_{if}$ that is $\varphi_m = (1 - R_{if})^{-\frac{1}{4}}$
- **Close to the MOST theory !**
- Coherence with the MOST : $\varphi_m = (1 - C_G.R_{if})^{-\frac{1}{4}}$ with $C_G = 4\beta_m\left(1 + \beta_m\frac{z}{L}\right)$ in stable atmosphere and $C_G = \gamma_m\left(1 + \gamma_m\frac{z}{L}\right)^{-\frac{1}{4}}$ in instable atmosphere with $\beta_m$ and $\gamma_m$ constants used in the universal stability functions as proposed by Businger et al (1971)

**Open question: Why do we need $C_G$?**

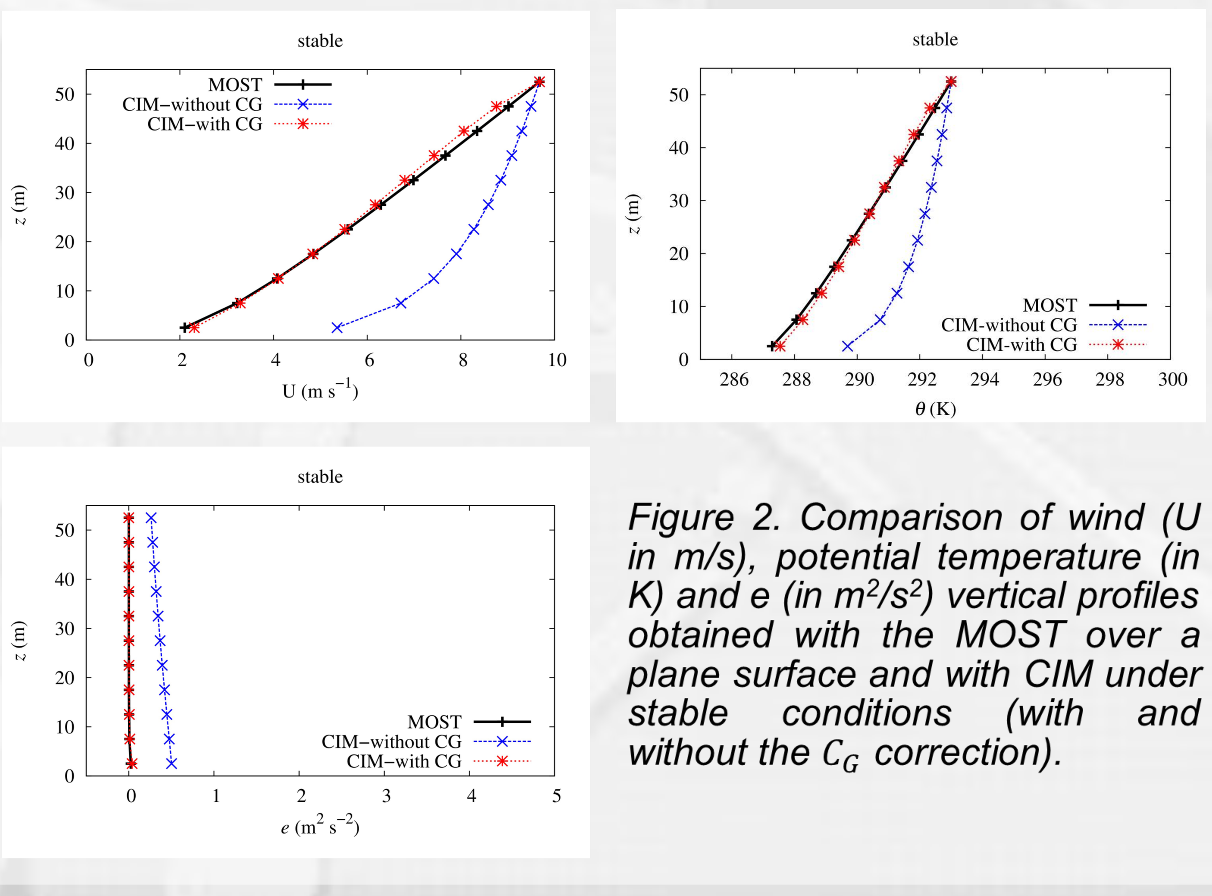


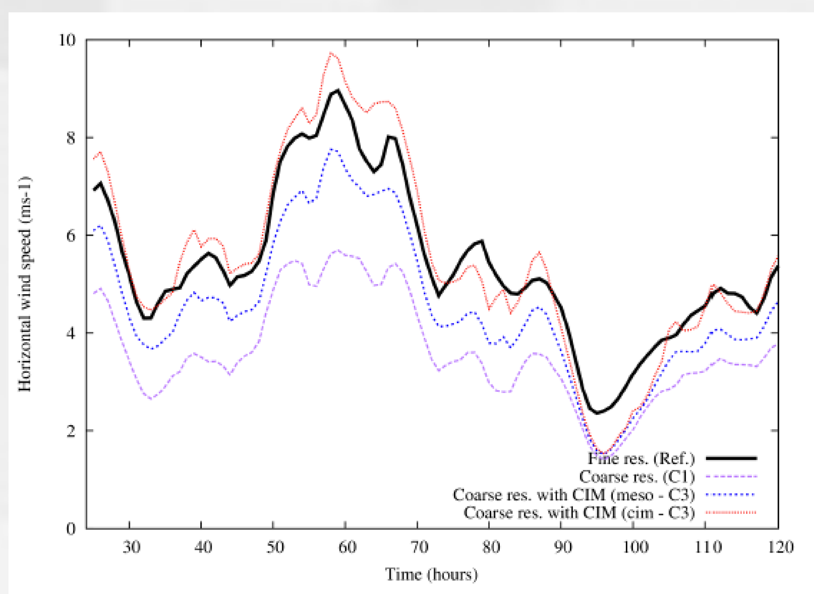

*Figure 2. Comparison of wind (U in m/s), potential temperature (in K) and e (in m²/s²) vertical profiles obtained with the MOST over a plane surface and with CIM under stable conditions (with and without the $C_G$ correction).*

## Applications : CIM in WRF

CIM was introduced in WRF so that the coupled system could provide high resolution meteorological profiles.

*Figure 4. Comparison of the hourly wind speed (in m/s) simulated by several WRF configuration at 50m :*

- *Ref. WRF with 5m vertical resolution*
- *C1. WRF with a first vertical level at 94m high*
- *meso C3. WRF+CIM*
- *cim C3. CIM results in WRF*




### You are also invited to listen :

- Mauree et al., Evaluation of building energy use: from the urban to the building scale (NOMTM11 - 24/Jul/2015: 2:15pm-4:00pm)
- Kohler et al., Could urban climate modelling systems provide urban planning guidelines in the context of building energy performance issues? (UDC6 - 24/Jul/2015: 11:00am-12:30pm)

**REFERENCES**

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- Charuchittipan D, Wilson JD (2009) Turbulent Kinetic Energy Dissipation in the Surface Layer. Boundary-Layer Meteorol 132:193-204. DOI 10.1007/s10546-009-9399-x
- Mauree, D. (2014) Development of a multi-scale meteorological system to improve urban climate modeling, Phd Unversié de Strasbourg.
- Santiago JL, Martilli A (2010) A Dynamic Urban Canopy Parameterization for Mesoscale Models Based on Computational Fluid Dynamics Reynolds-Averaged Navier-Stokes Microscale Simulations. Boundary-Layer Meteorol 137:417-439. DOI 10.1007/s10546-010-9538-4

**ACKNOWLEDGMENTS**

*The authors would like to thank the French Environment and Energy Management Agency ADEME for financial support through the phd of D. Mauree, ZAEU and REALISE networks.*

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