CFD Simulation and Comparison with Measurements for Flow and Dispersion in a Neighborhood of Marseille Including thermal and radiative efects

Yongfeng Qu, Maya Milliez, Bertrand Carissimo*

CEREA ENPC / EDF R&D, Chatou, Île-de-France, France

carissim@cerea.enpc.fr

Cerea

Centre d'Enseignement et de Recherche en Environnement Atmosphérique

École des Ponts ParisTech

UNIVERSITÉ PARIS-EST

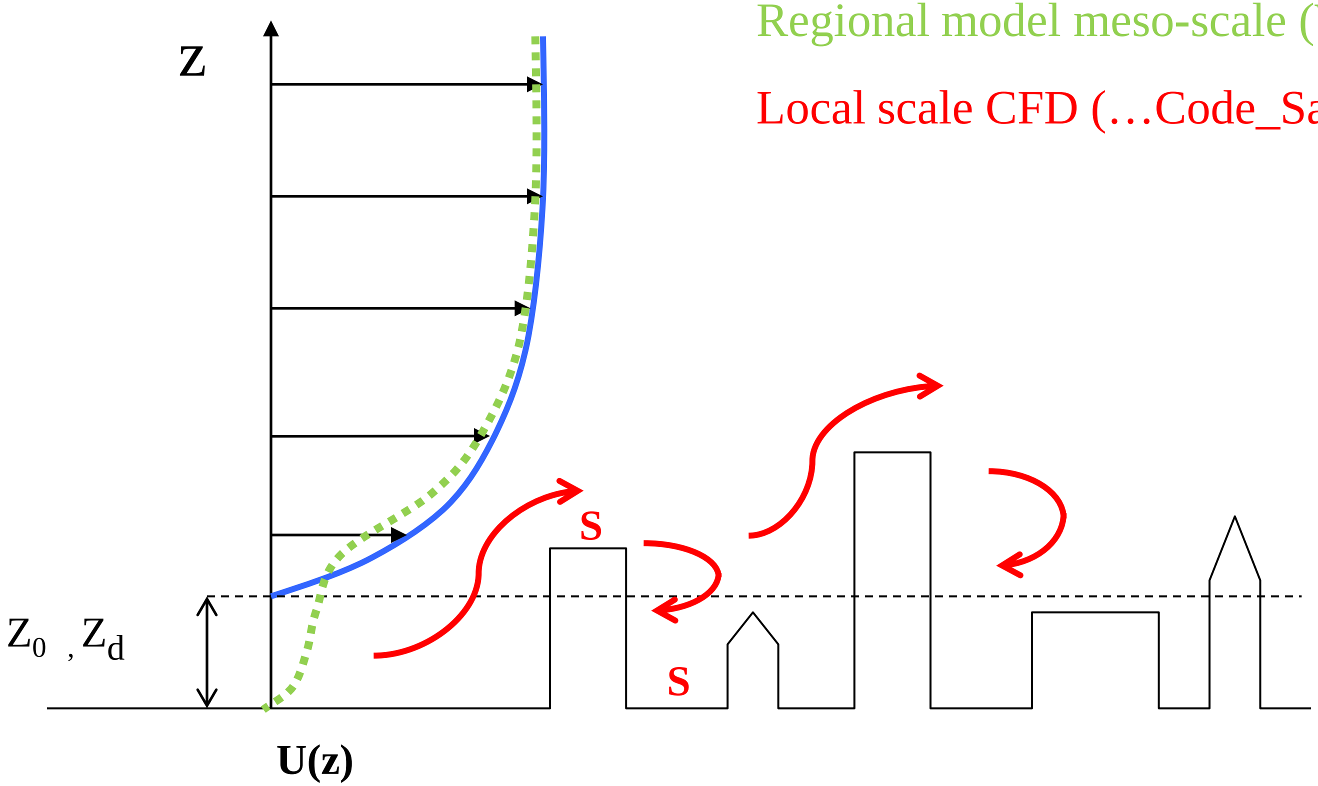
EDF R&D

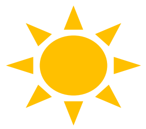
Effect of the built environment :

Continental-global model $\Delta x = 10km$

Regional model meso-scale (WRF…) $\Delta x = 1km$

Local scale CFD (…Code_Saturne …) $\Delta x = 10m$





- **Thermal + radiation**
- **Water cycle**

➔ our recipe

➔ indutrial site, urban neighborhood, wind farm …

➔ Start with a standard open source CFD code :
(www.code-saturne.org)

- Finite volume, unstructured mesh
- T, H thermal variables
- Parallel code (10^9 nodes, 10^6 procs) …

➔ Add some atmospheric physics :

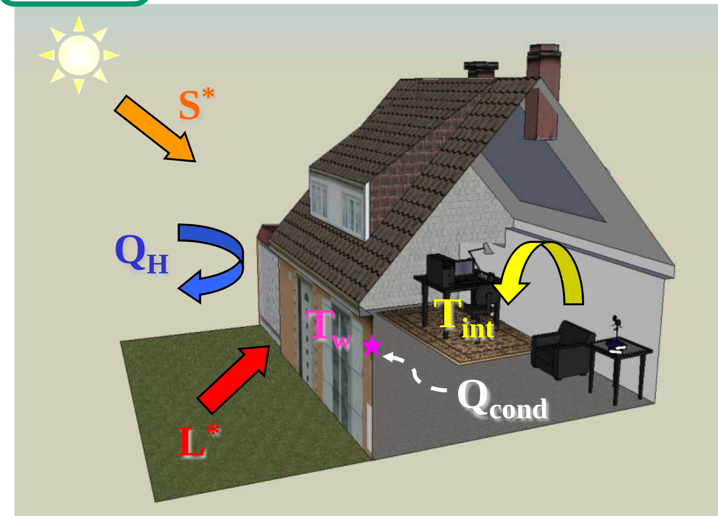
- « dry atmosphere » : $\theta = T\left(\frac{p_0}{p}\right)^{\frac{r}{C_p}}$ > 2.0
- « humid atmosphere » : $\theta_l \quad q_w \quad N_c$ > 3.0

(cooling towers, fog formation, green roofs …)

+ modified turbulence buoyancy production

➔Add atmospheric wall laws : > 2.0
roughness + Louis (Ri) / Monin Obukhov

➔Add soil / building models : > 3.0



- Ground: Force-restore model (Deardorff, 1978)

$$\frac{\partial T_g}{\partial t} = \frac{\sqrt{2\omega}}{\mu_g} Q_g^* - \omega (T_g - T_{g\,\mathrm{int}})$$

$$Q_w^* = L^* + S^* - Q_H - Q_{LE} - Q_F$$

- Building walls: Wall thermal model

$$\underbrace{\frac{\lambda_w}{e_w}(T_w - T_{w\mathrm{int}})}_{Q_{cond}} = \underbrace{h_f (T_a - T_w)}_{Q_H} + \underbrace{\varepsilon_w (L_a + L_e - \sigma T_w{}^4)}_{L^*} + \underbrace{(1-\alpha)(S_D + S_f + S_e)}_{S^*}$$

➔add a zest of atmospheric radiative effects

- **1D classical model (// approx., absorption)**

> 3.0

- **3D radiative model :**

❑ Discrete Ordinate Method (DOM)

❑ Spatial discretization uses the same mesh as the CFD model (not surface view factors)

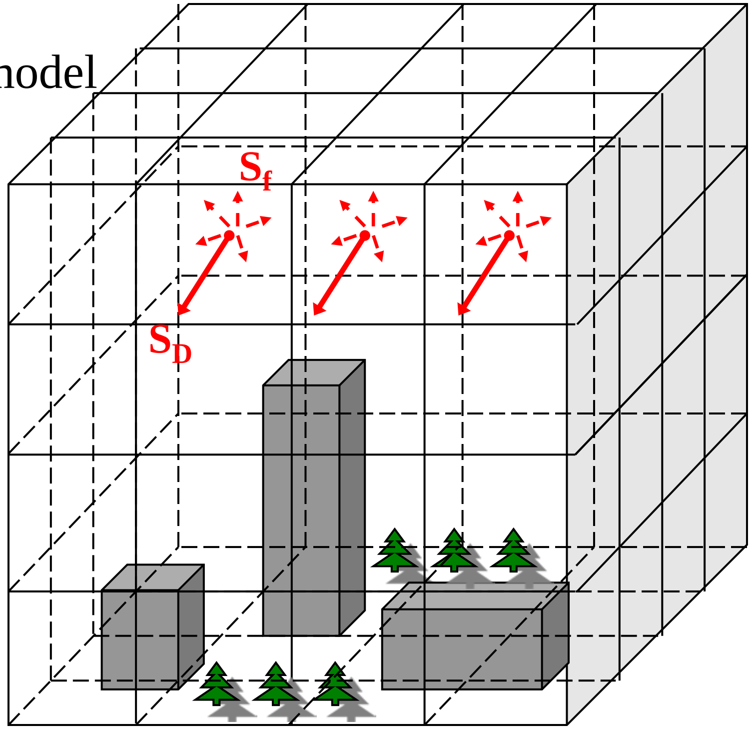
❑ Short and long-wave radiation surface budget:

$$S^{\downarrow} = S_D + S_f + S_e$$

$$S^{\uparrow} = \alpha S^{\downarrow}$$

$$L^{\downarrow} = L_a + L_e$$

$$L^{\uparrow} = \varepsilon \sigma T_w^4 + (1-\varepsilon)(L_a + L_e)$$



➔add an atmospheric chemistry scheme : > 3.0

- take the AQ gas chemistry solver from Polyphemus regional system : (open_source : cerea.enpc.fr/polyphemus)
- Can choose a scheme suited to small scale reactive dispersion (eg : 4 or 31 species …)

➔add an aerosols particle formation : > 3.0

- Also from Polyphemus
- Adaptated to near source higher T
- [Modal model (MAM)]
- Size resolved (SIREAM)

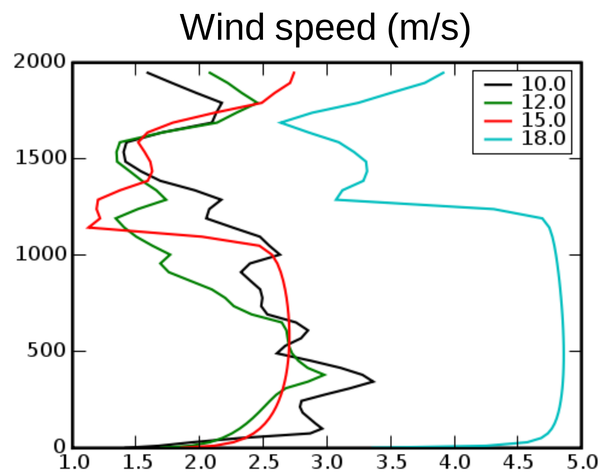
➔check your ingredients: Verification & Validation

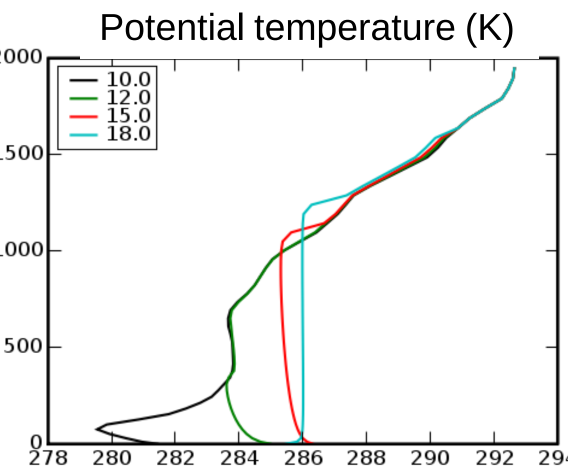
- ....
- Diurnal cycle of the atmospheric boundary layer (Wangara experiment)
- CAPITOUL field data(central Toulouse)
- ....

Code_Saturne: validation on Wangara experiment

- **Experiment often used to test the ability of models to reproduce the diurnal cycle**
- **Vertical profiles of wind speed and potential temperature**

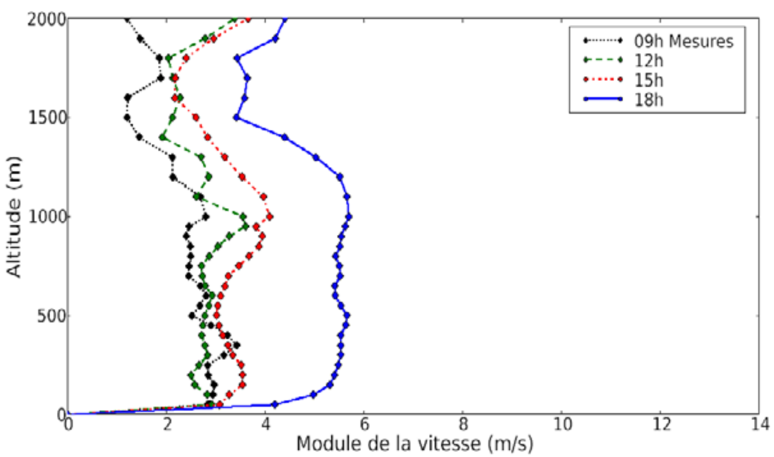
Unstable (day)

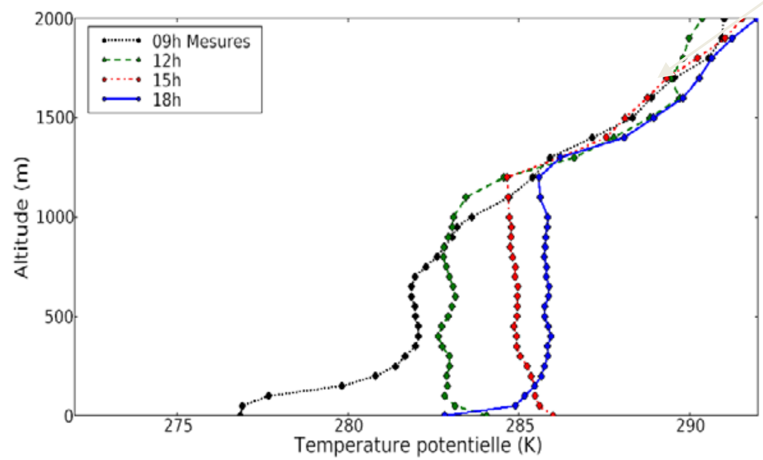




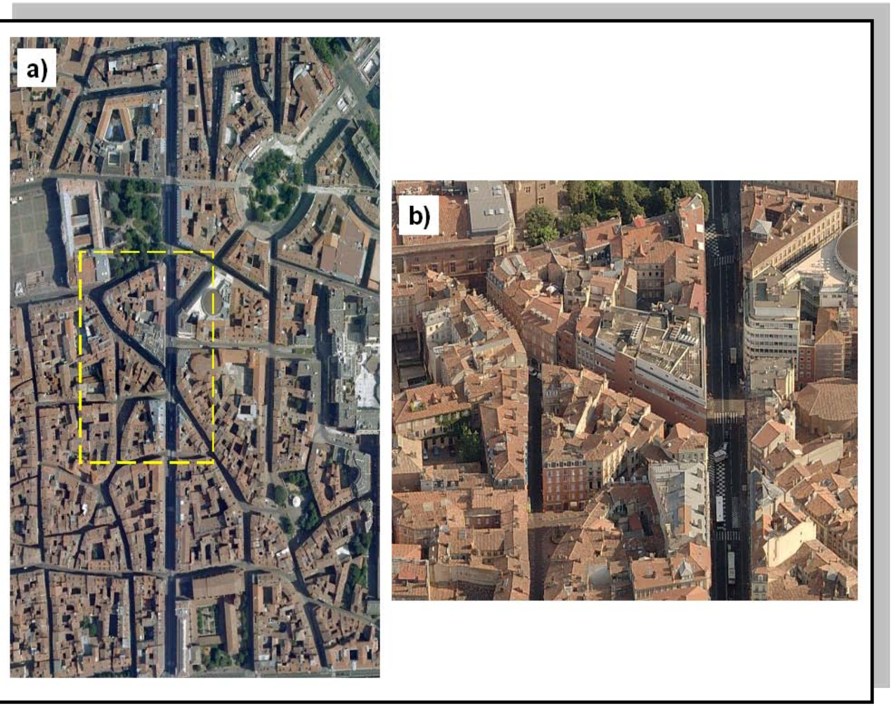
calculated

measured

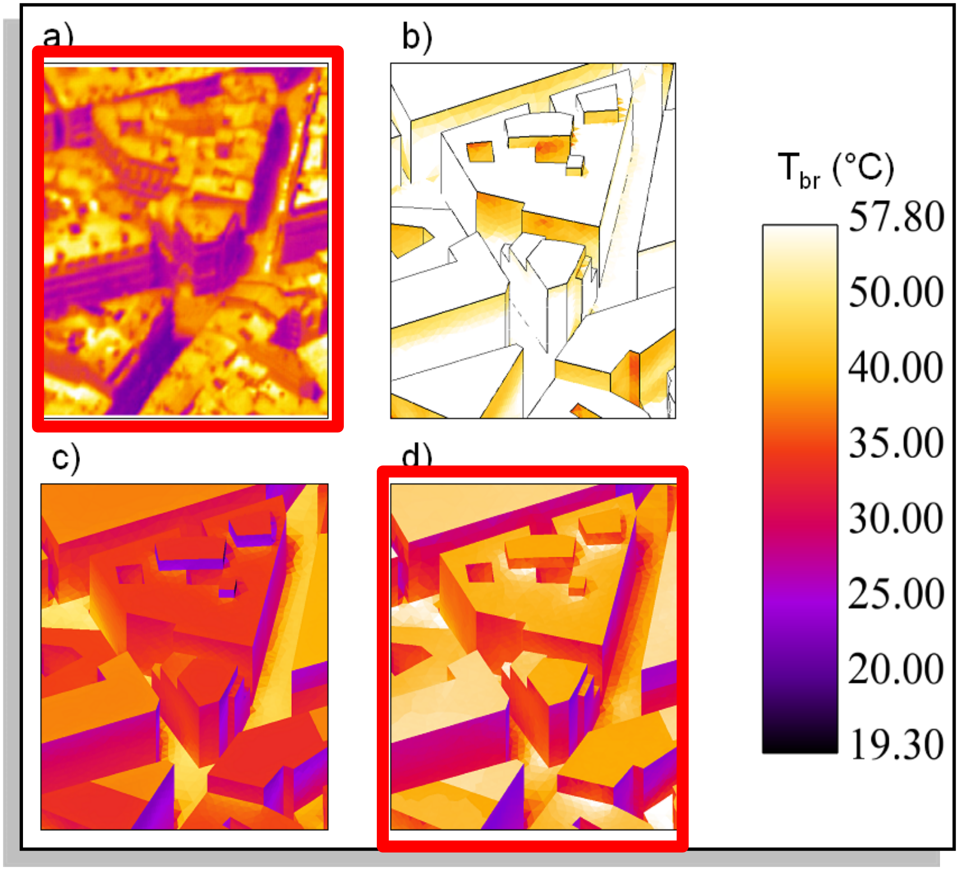




Validation with field campaign in Toulouse (CAPITOUL, Masson et al. 2005)



CAPITOUL (2004)

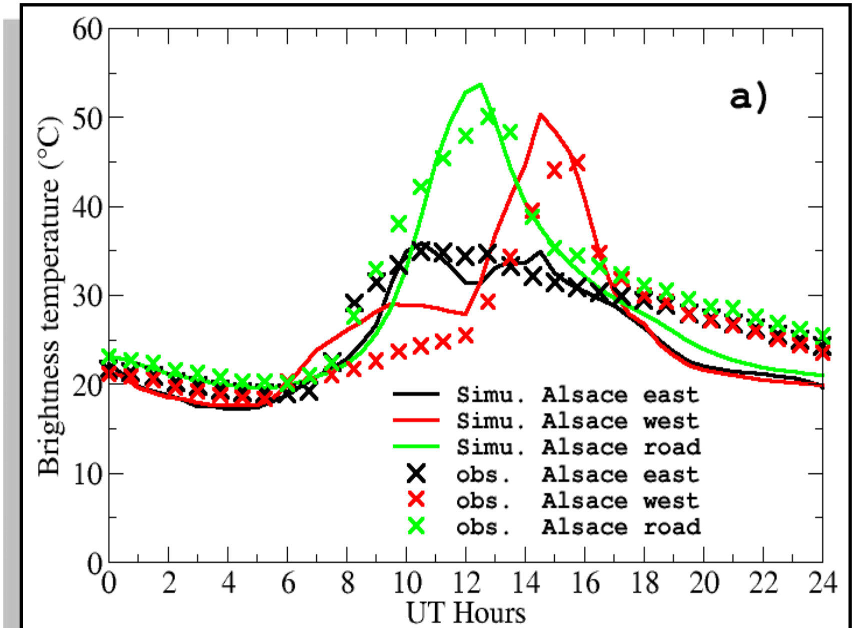


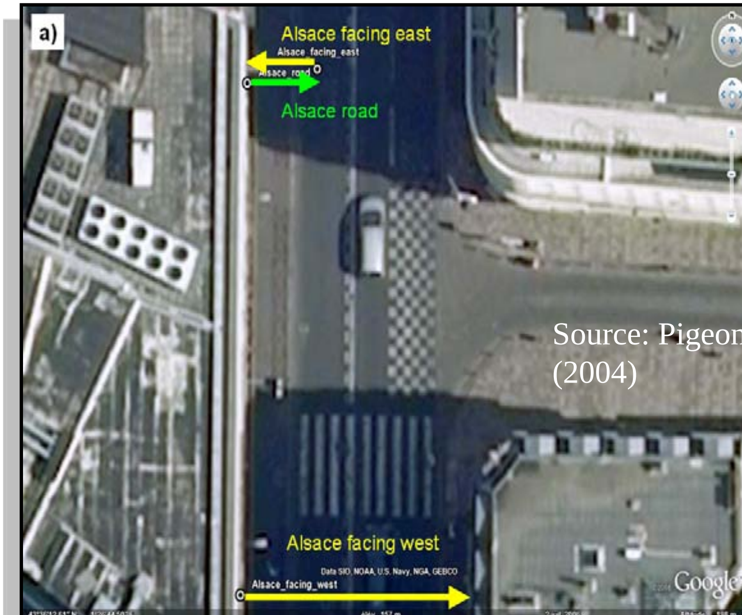
a) Measured Source: Hénon (2008) c) Simulated T_{br} with h_f constant

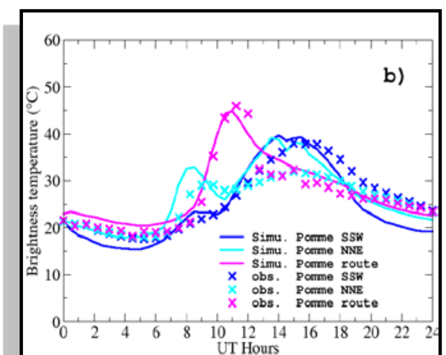
b) Simulated T_{br} without wind d) Simulated T_{br} with full coupling

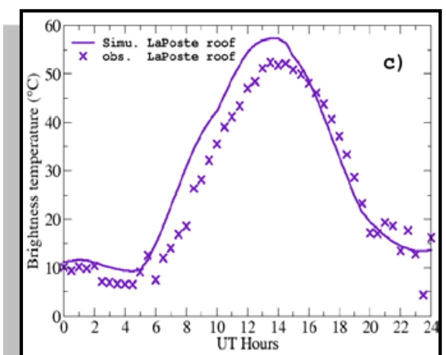
Validation with CAPITOUL field campaign

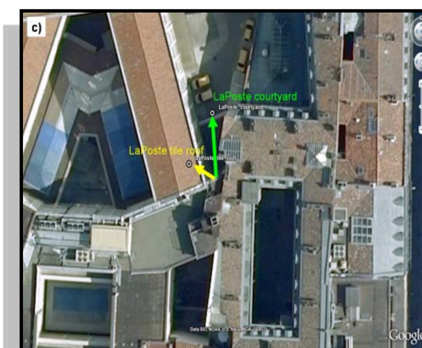
- Simulation of July 15th 2004 (24 h simulation)
- Diurnal evolution for T_{br} of different positions of the infrared thermometers







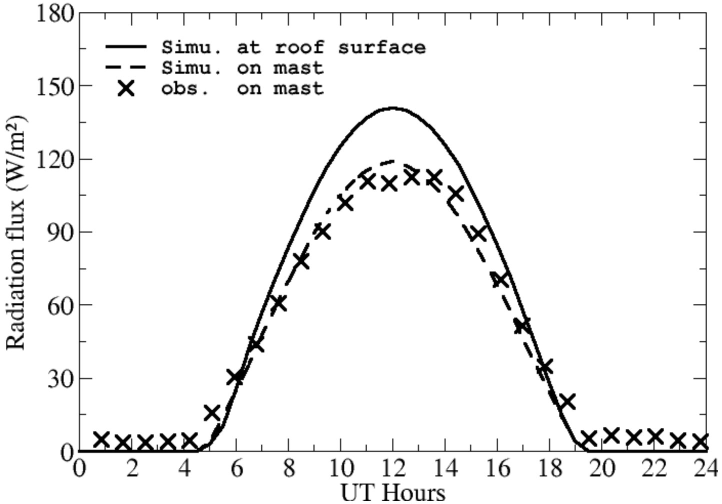




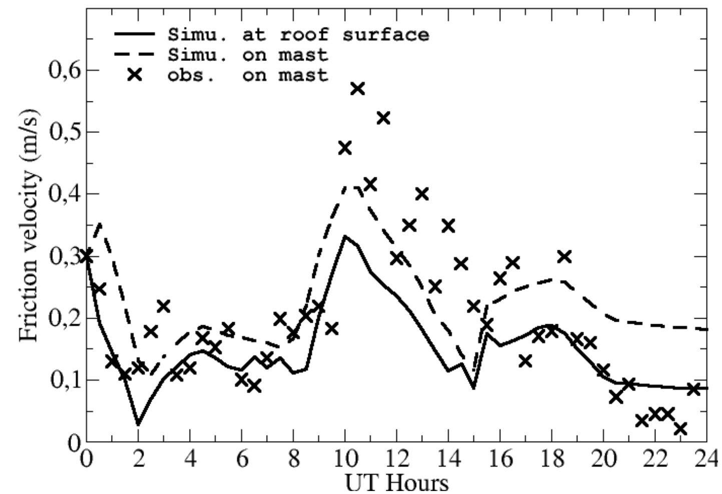
Validation with CAPITOUL dataset (Qu, 2012)

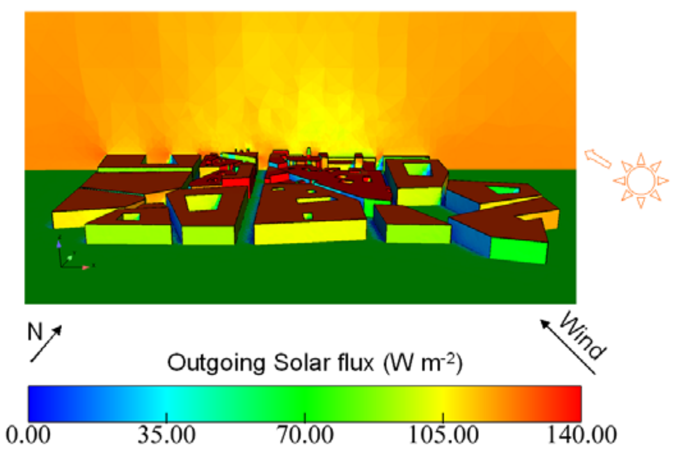
- Simulation of July 15th 2004, meteorological mast comparisons

❑ Comparison of outward solar flux



❑ Comparison of friction velocity





At roof surface: $u^{*}=(\,|\,\tau_w/\rho\,|\,)^{1/2}$

On the mast: $u^{*}=(\underline{u'w'}^{2}+\underline{u'w'}^{2})^{1/4}$

Approach for Marseille

QUALITÉ ENVIRONNEMENTALE DES QUARTIERS

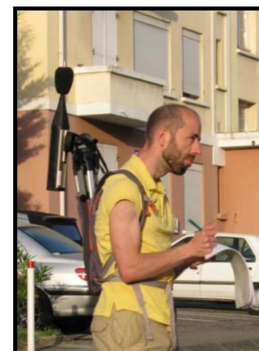
EUREQUA ANR BVD 2011

- **Multidisciplinary approach involving physical and social sciences.**
- Understand and model different parameters of the physical environment and their interactions: climate, noise and air quality.
- A geographical and social approach to explore the “subjective” dimension of the environmental quality, based on perceptions and representations.
- Work on three neighborhoods of cities – Toulouse, Paris and Marseilles - already invested by the project partners, on relevant areas (rehabilitation projects and environmental issues)

(Marseille, june 2013)

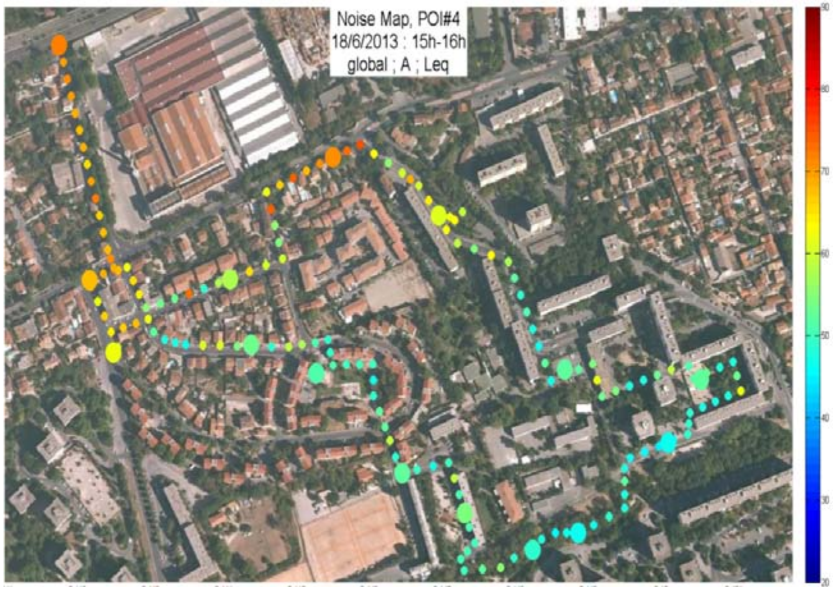
EUREQUA
QUALITÉ ENVIRONNEMENTALE DES QUARTIERS
ANR BVD 2011

Réseau fixe météo
Réseau fixe QA
Circuit mesures physiques
Circuit physiques/enquêtes
Sonomètre fixe
Comptage trafic



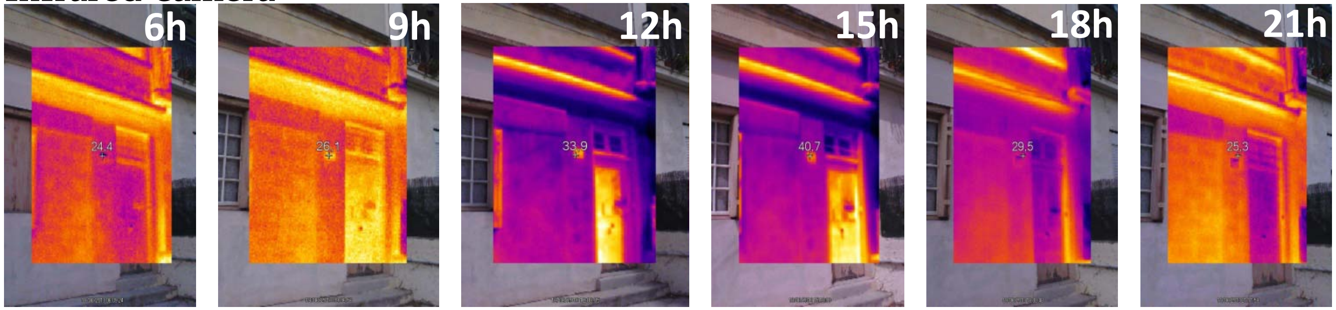
Example of results from mobile stations

Sound level (mobile mesurement)



Air temperature (mobile mesurement)

Infrared camera

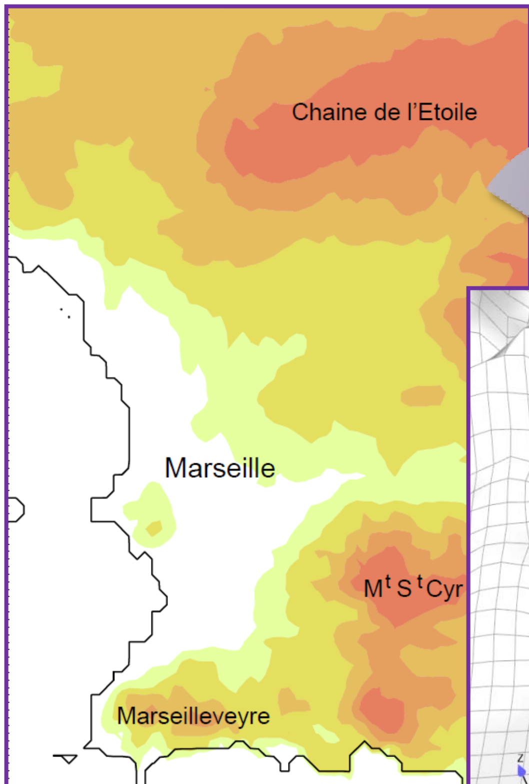


Numerical modeling :

3 - levels

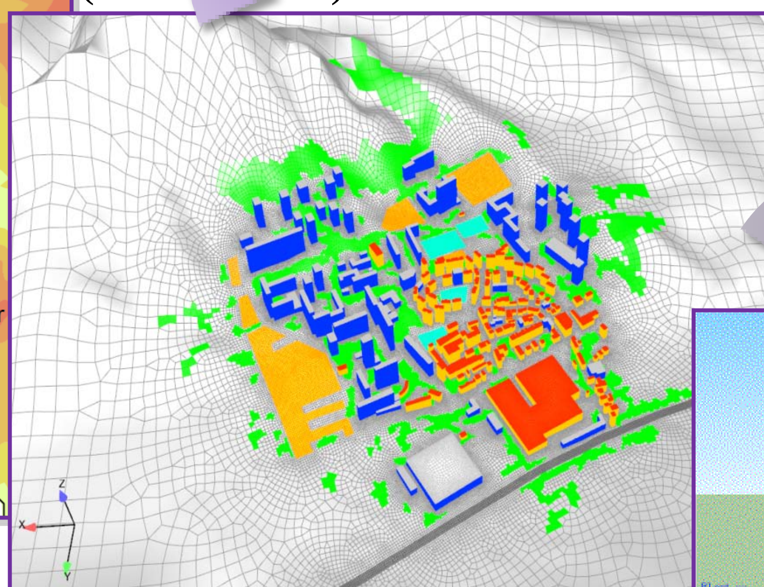
Modèle dyn de trafic
(ou comptage)

Modèle météo MESO-NH



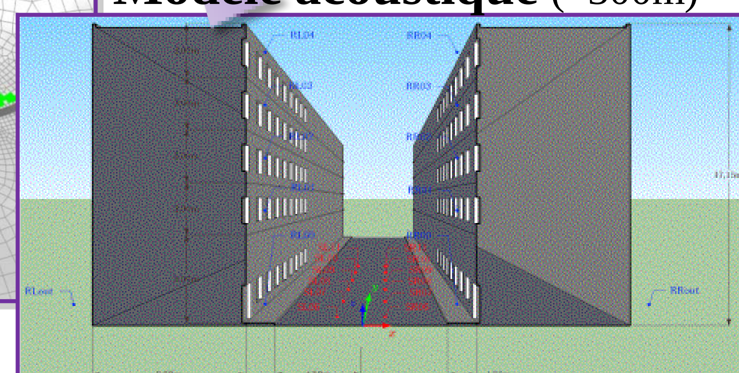
Boundary conditions

Modèle CFD+thermo-radiatif
(800m x 500m)

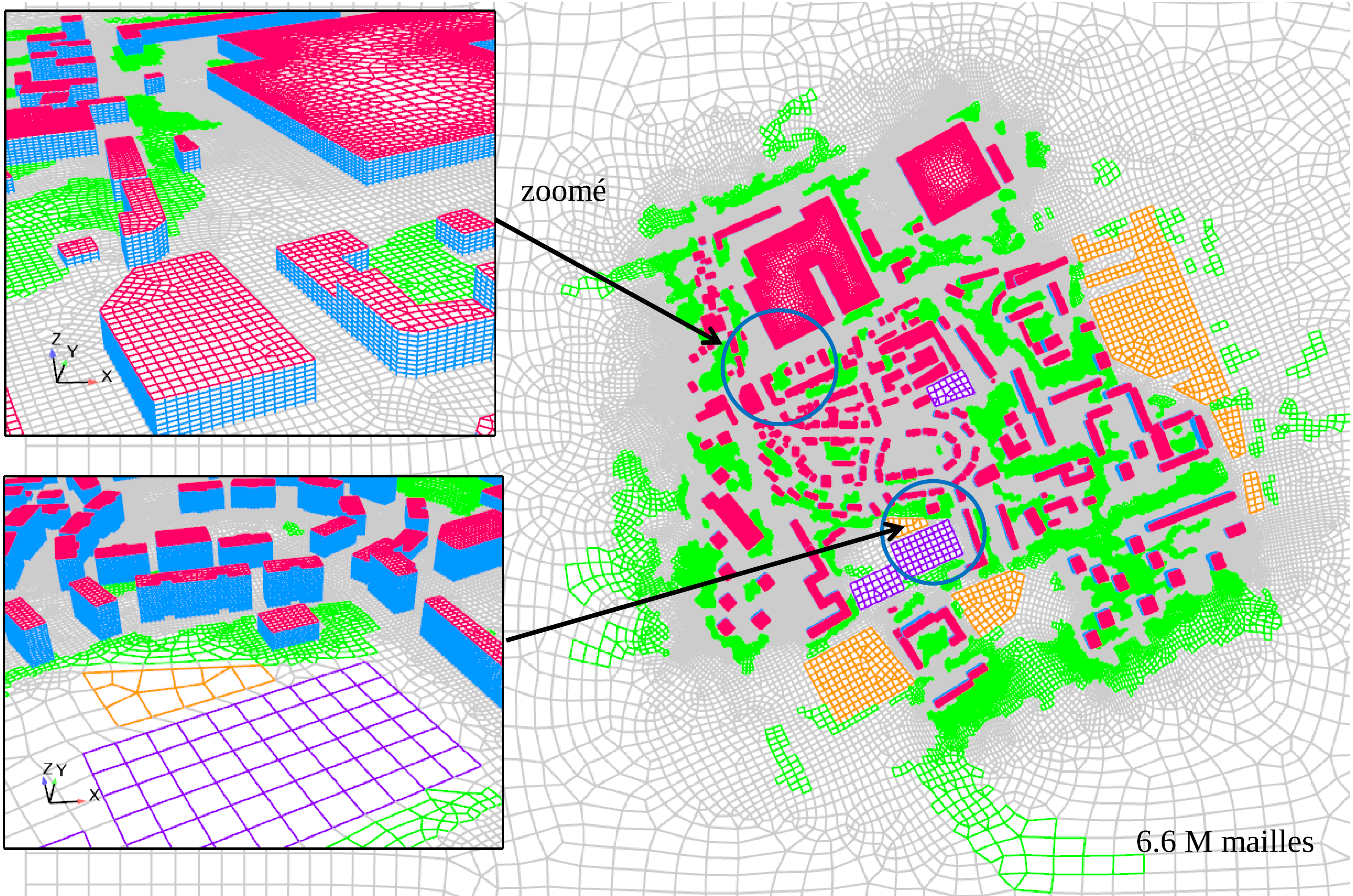


Champs micrométéo

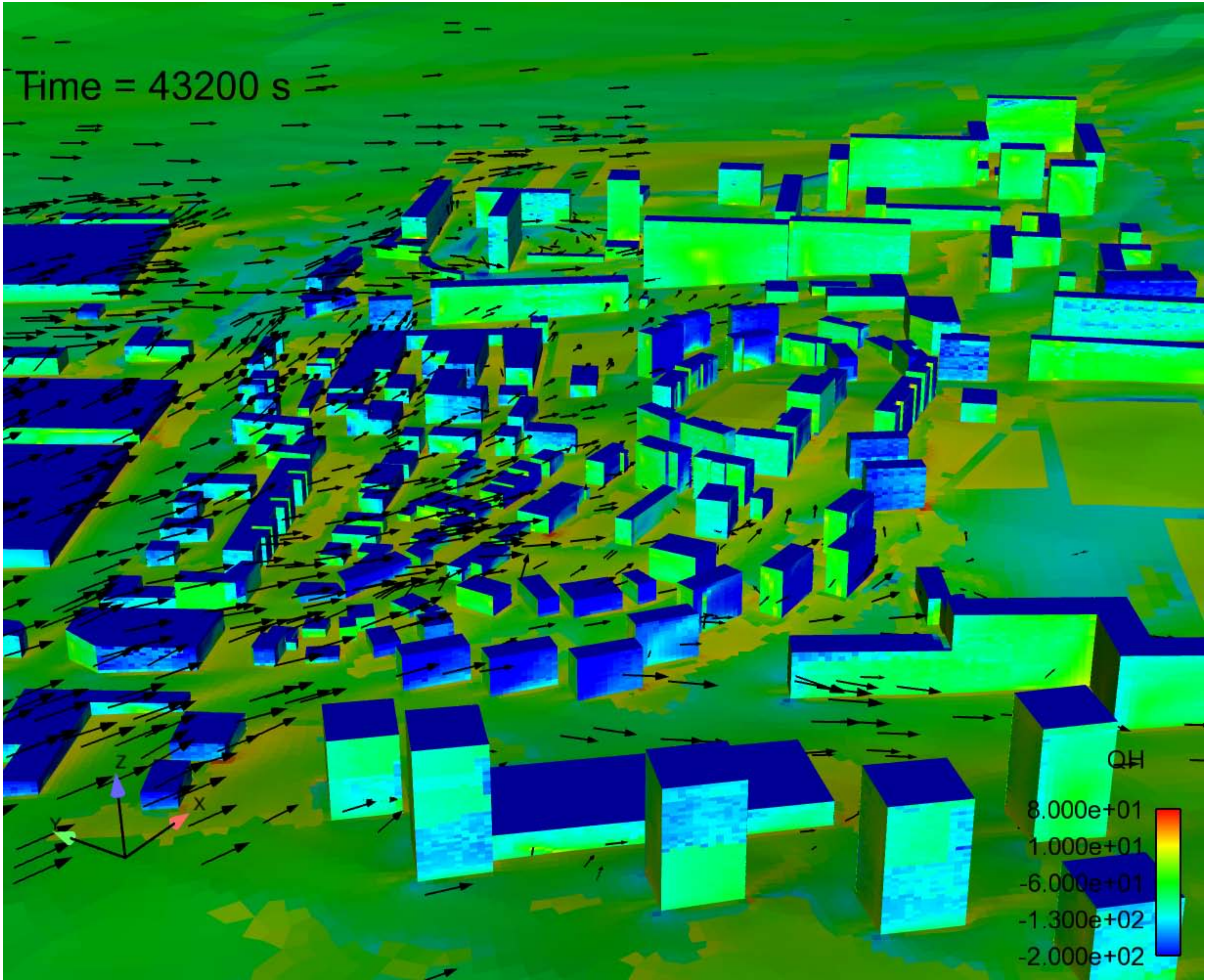
Modèle acoustique (~300m)



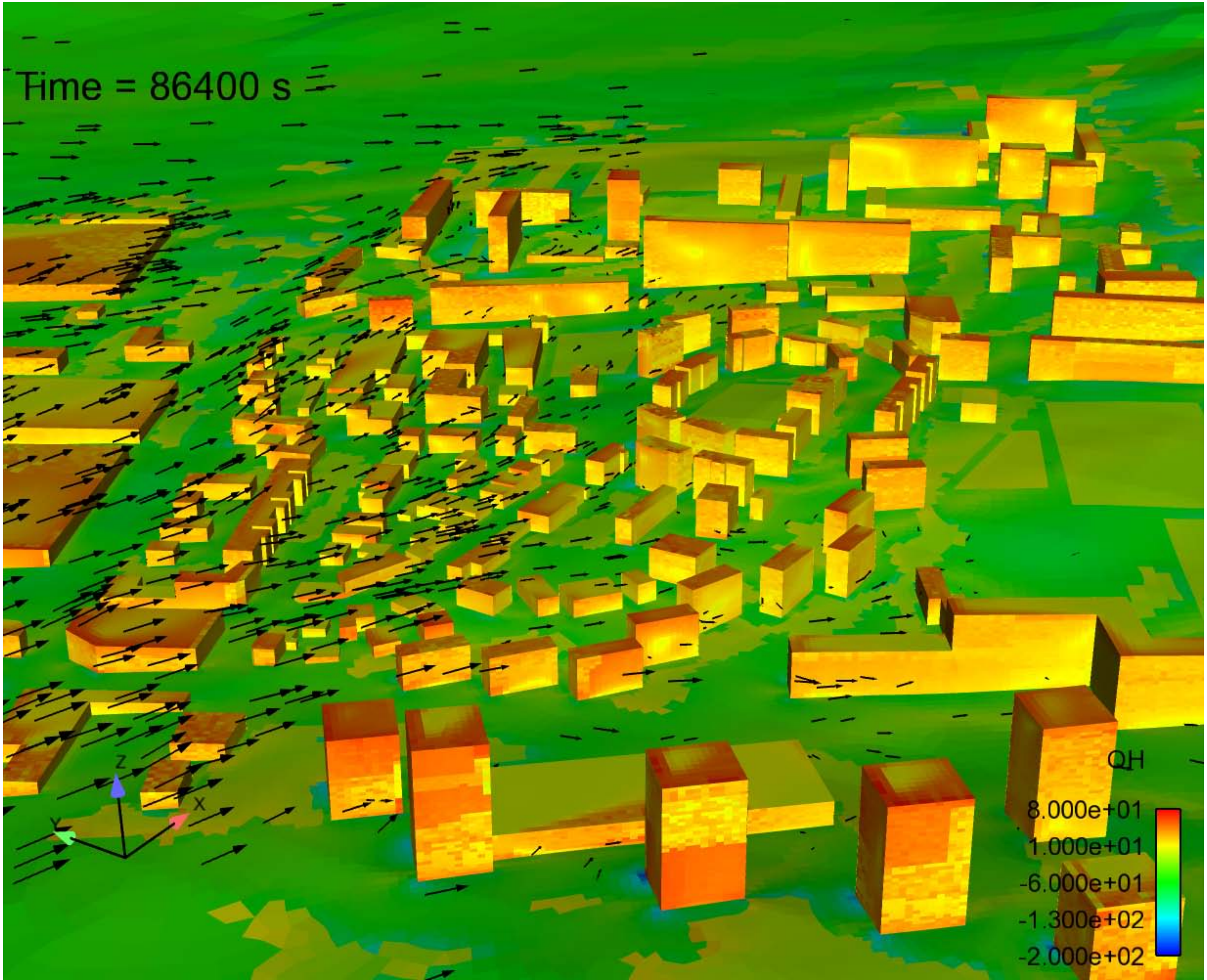
Grid: Buildings + Block+ Vegetation + sport area



Wind at z= 55m ASL and heat flux from the building : at 12h

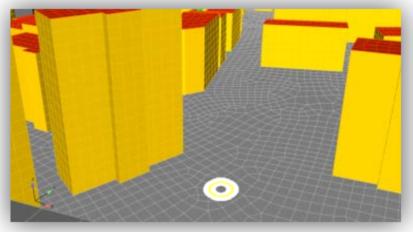


Wind at z= 55m ASL and heat flux from the building : at 24h

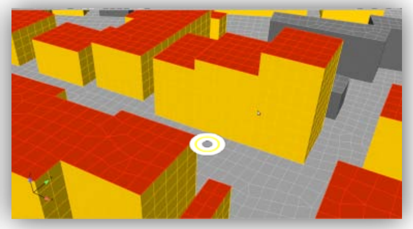


Marseille : stop points from mobile instruments (Infrared Images)

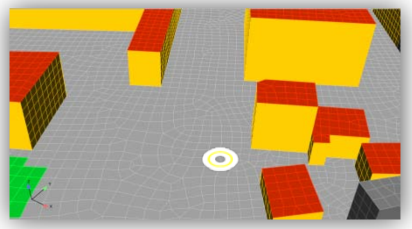
C1



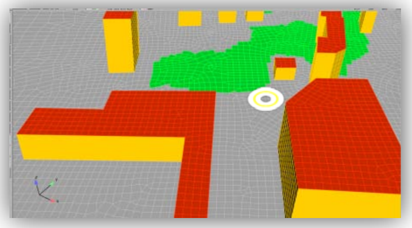
C2



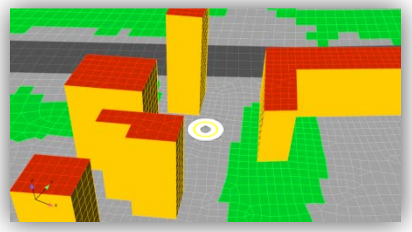
C3



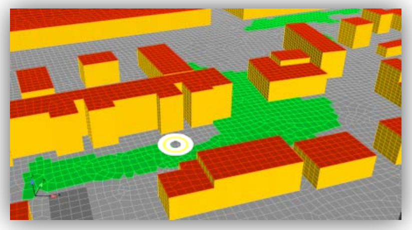
C4



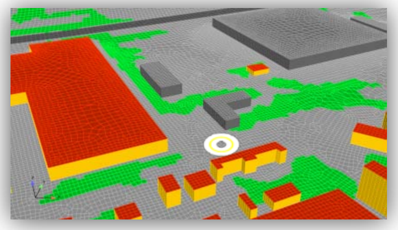
C5



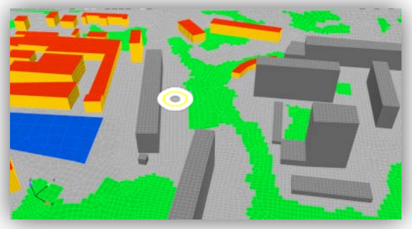
C6



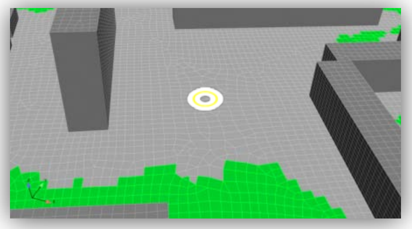
C7



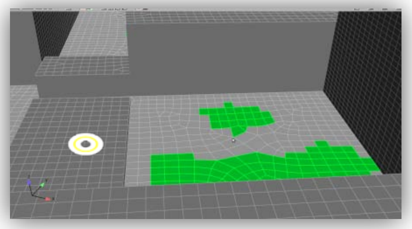
C8



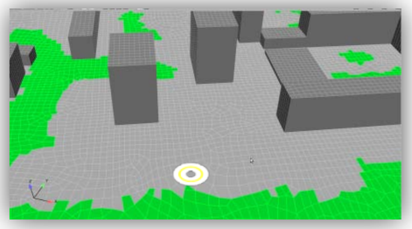
C9



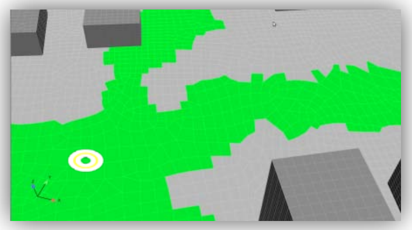
C10



C11



C12



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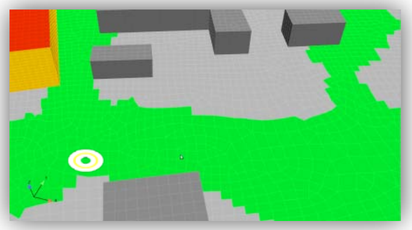

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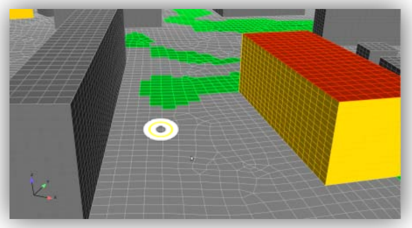
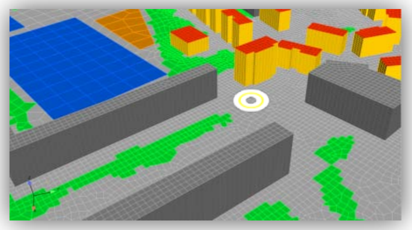


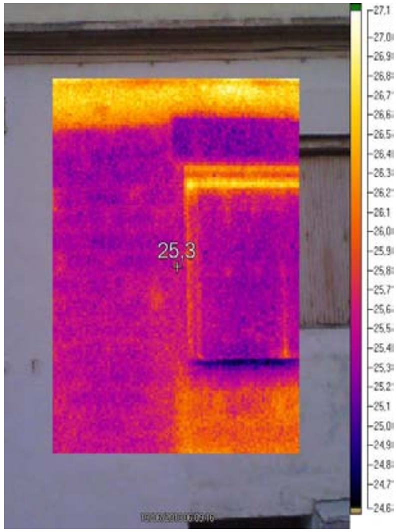
C15



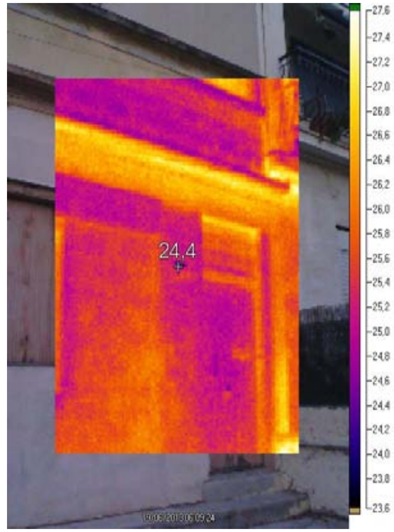
Infrared superposed to visible images for point C2
19 june 2013 at 6 h for 8 directions :

> 12 000 IR images

N

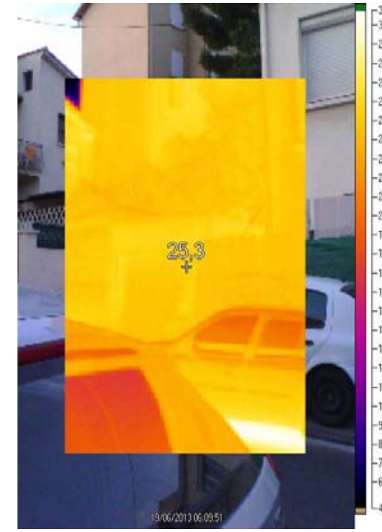


NE

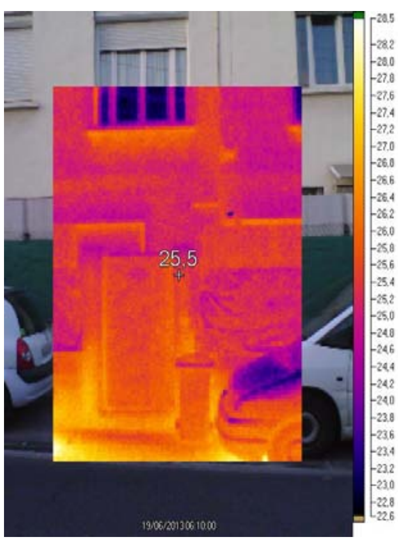


E

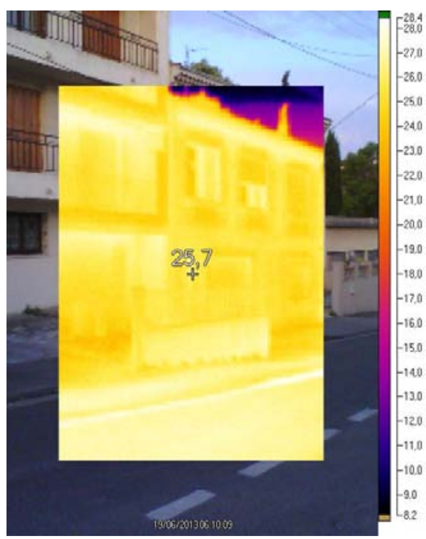
SE



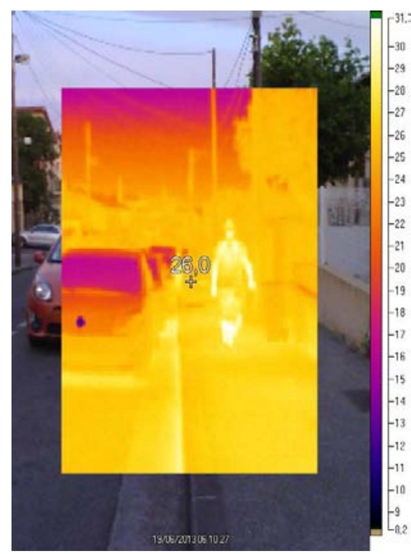
S



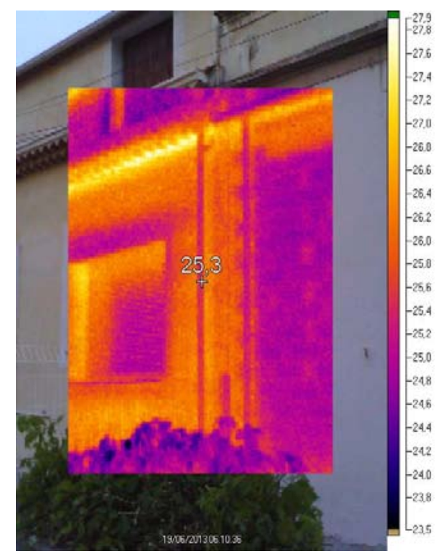
SO



O



NO



Conclusions - Perpectives

- On going comparaison with fixed stations and mobile measurements, including IR images
- Add local contribution to air quality (main roads)
- Use measured winds (RS + ground stations) then couple with Meto-France model (Meso-NH)
- Rerun for scenario of city modifications
- Provide simulation results for accoustic studies and social sciences