Evaluating the urban climate using geo-database: GEOCLIM TOOL

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INTRODUCTION

Need for tools to assess the urban planning impact on UHI that are:

- Simple
- Based on commonly available data

Previous researches show that UHI is strongly linked to urban form and land use

- SVF (Chen et al., 2012; Gál, Lindberg, & Unger, 2009; Lindberg, 2007; Unger, 2004, 2009…)
- Urban vegetation (Takehiko &Yasushi, 2009 ; Cao et al., 2010; Shashua-Bar & Hoffman 2004…)

OVERVIEW

I.   Method

II. Urban form characterization

III. Analytical formulation of SW radiation
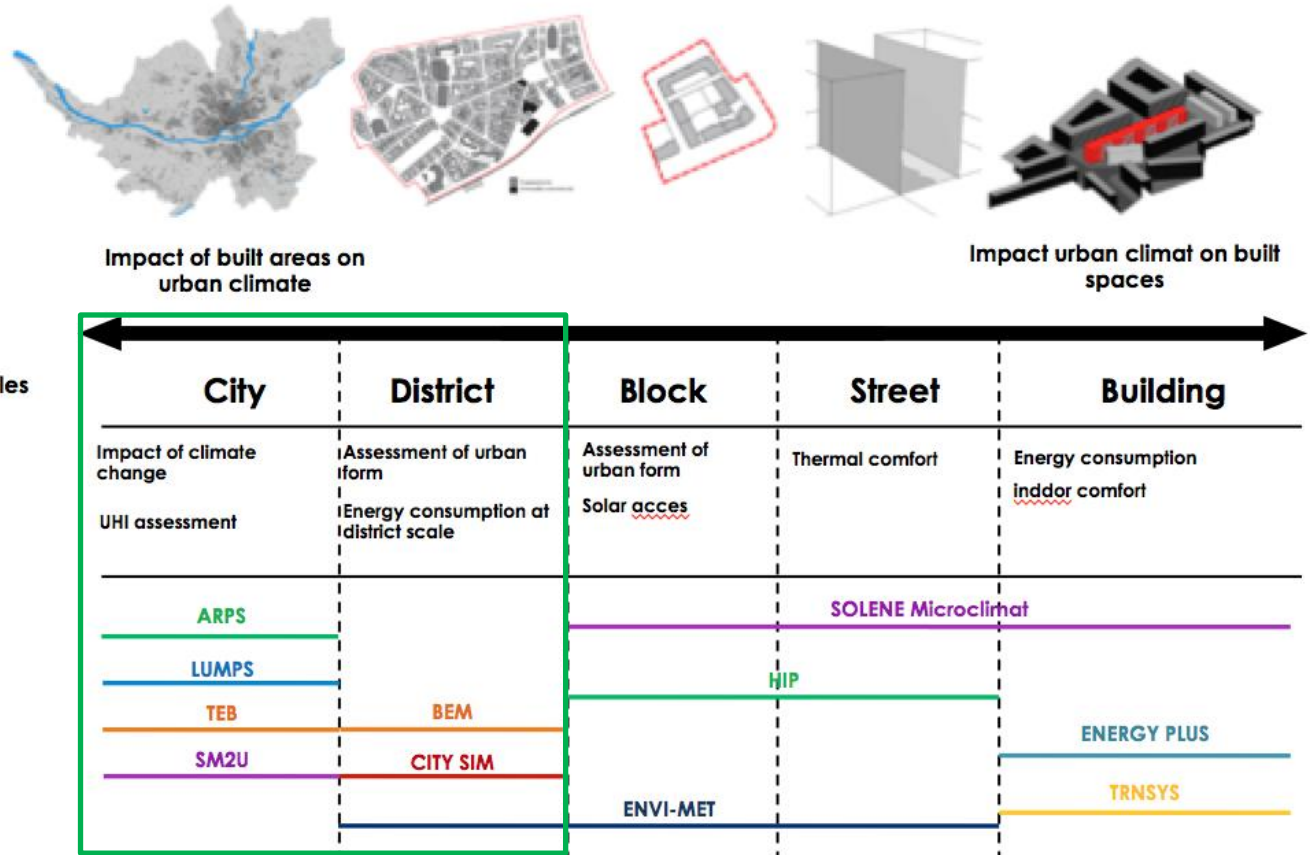
IV. Model construction

V.   Conclusions

I. Method

I. METHOD

1. Scale

2. Urban unit: the urban block

I. METHOD
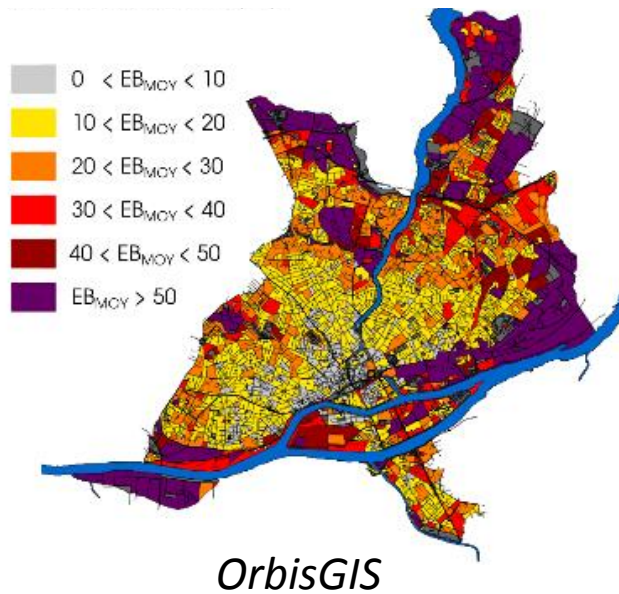
3. Urban typology
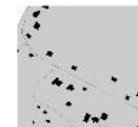
Ex: Mean space between buildings

OrbisGIS
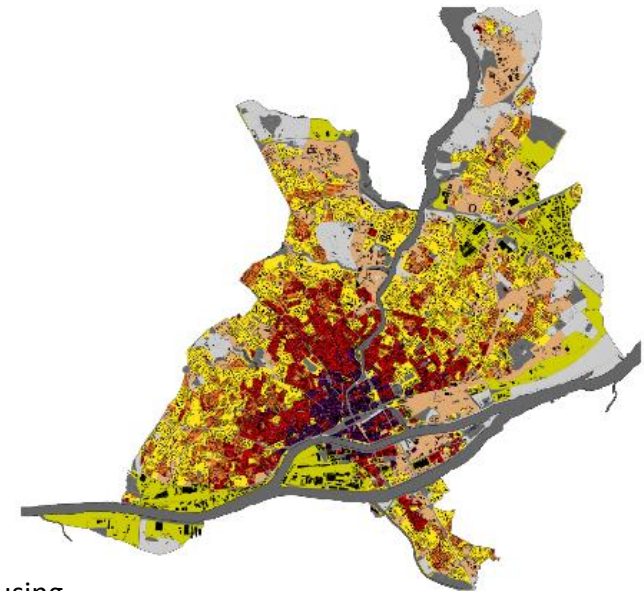
City center

Suburban

Discontinued housing

Continued housing
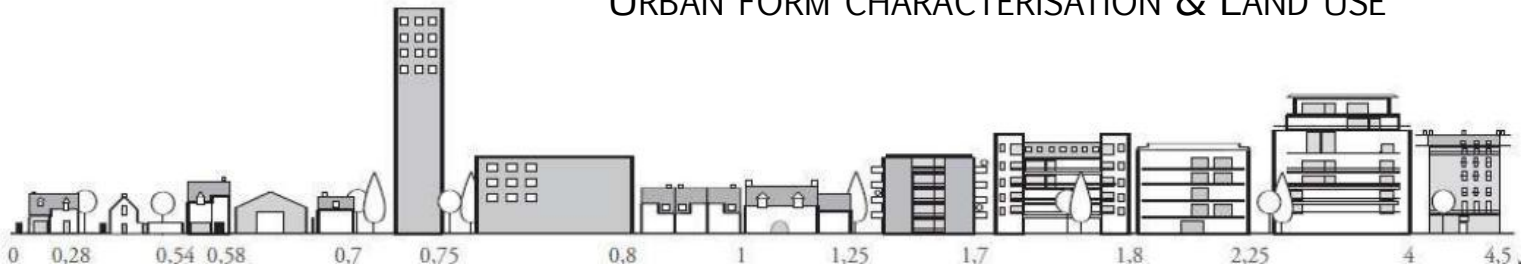
Scattered housing

Collective buildings

Industrial areas

4. Model

URBAN FORM CHARACTERISATION & LAND USE

0   0,28   0,54 0,58   0,7   0,75   0,8   1   1,25   1,7   1,8   2,25   4   4,5

① ② ③ ④ ⑤

SW Rᴀᴅɪᴀᴛɪᴠᴇ Mᴏᴅᴇʟ

LW Rᴀᴅɪᴀᴛɪᴠᴇ Mᴏᴅᴇʟ

Tʀᴀɴsғᴇʀ ɪɴ ʙᴜɪʟᴅɪɴɢs ᴀɴᴅ sᴏɪʟ

ᴀssᴇᴍʙʟɪɴɢ : Aɪʀғʟᴏᴡ - Aᴅᴠᴇᴄᴛɪᴠᴇ ᴍᴏᴅᴇʟ

II. URBAN FORM CHARACTERIZATION

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Simple calculation: performed in a GIS
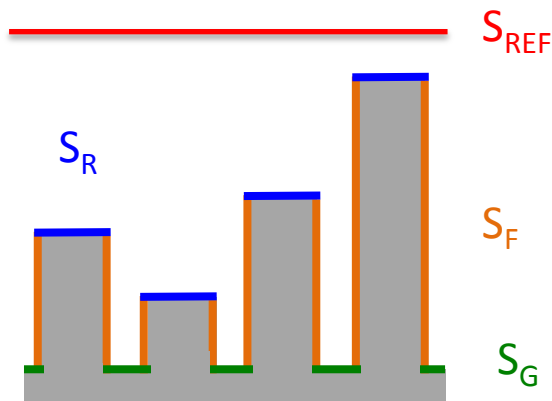
Calculation for wich a 3D model is needed

Built density

Facade density

$$D_B = S_{ROOF}/S_{REF}$$

$$D_F = S_F/S_T$$

Sky-view factor

S_{REF}

S_R

S_F

S_G

$$S_T = S_G + S_F + S_R$$
$$= S_{REF} + S_F$$
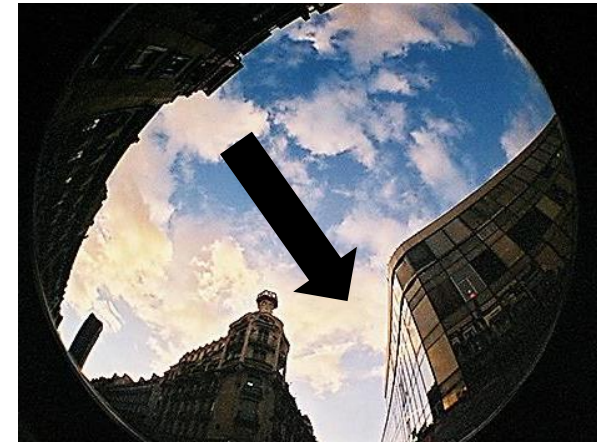
II. URBAN FORM CHARACTERIZATION

SVF as a function of facade density
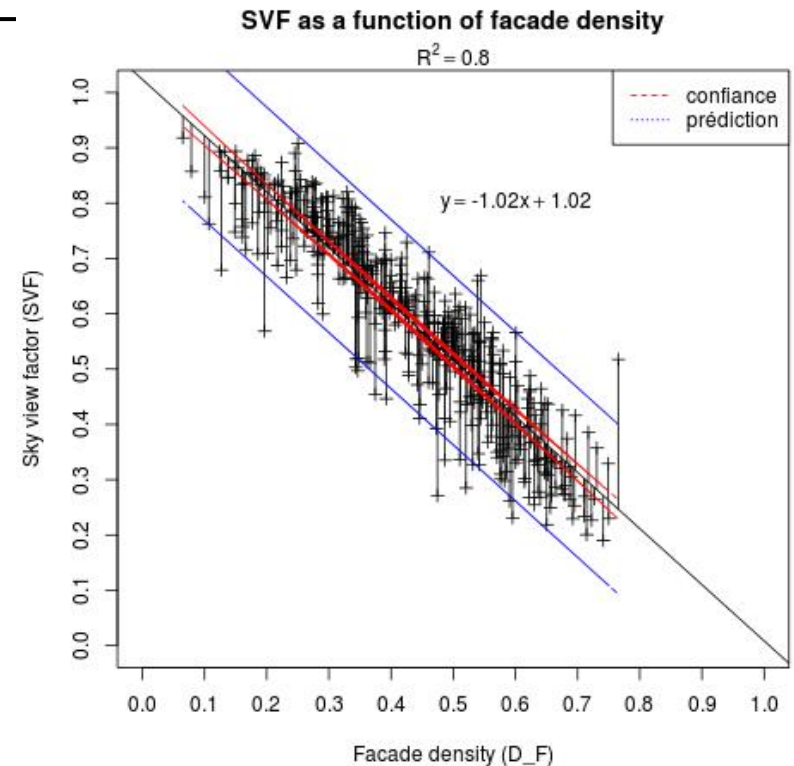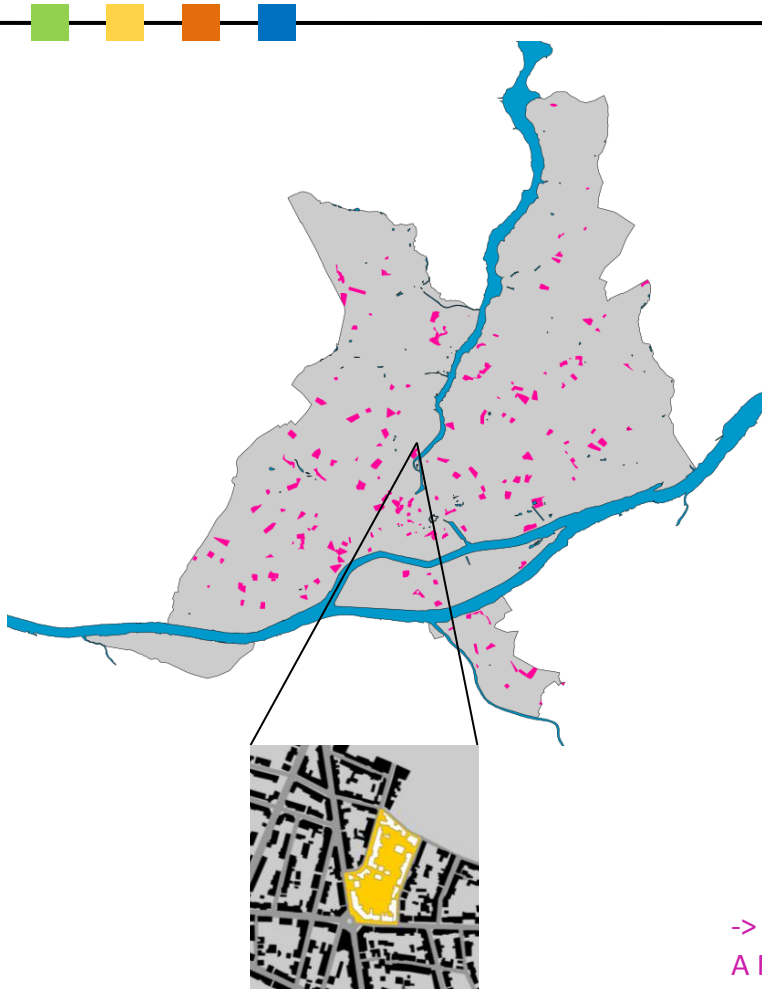
$SVF_{BLOCK}=1-D_F$

-> see: Groleau, D., Mestayer, P., 2013. Urban Morphology Influence on Urban Albedo: A Revisit with the Solene Model. Boundary-Layer Meteorology 147, 301–327.

Bernabé, A. et al.. Radiative and heat storage properties of the urban fabric derived from analysis of surface forms. Urban Climate.

III. ANALYTICAL FORMULATION OF SW RADIATION
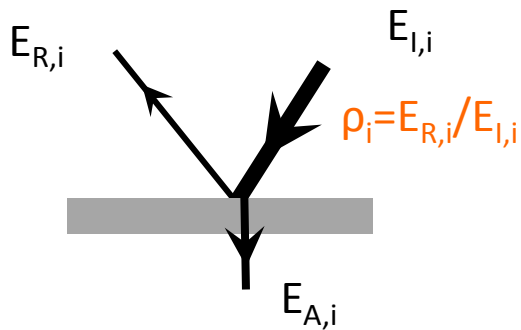
III. ANALYTICAL FORMULATION OF SW RADIATION

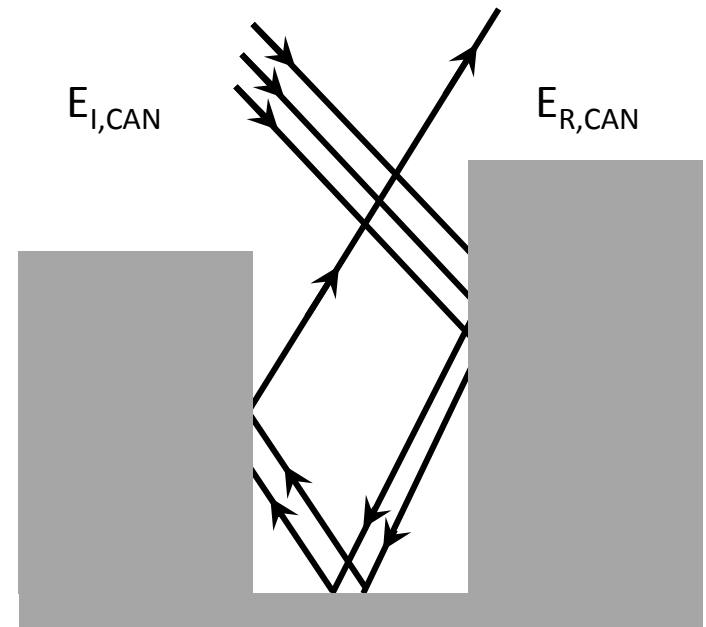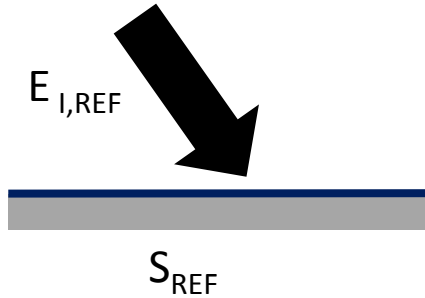## 1. Radiative trapping formulation

Multiple reflections in the urban form

Surface albedo

$E_{R,i}$ $E_{I,i}$

$\rho_i = E_{R,i}/E_{I,i}$

$E_{A,i}$

$E_{I,CAN}$ $E_{R,CAN}$

Equivalent albedo

$\rho_{CAN} = E_{R,CAN}/E_{I,CAN}$

III. ANALYTICAL FORMULATION OF SW RADIATION

$E_{I,REF}$

S_{REF}

$E_{I,BLOCK}$

$S_{REF} + S_F$

Using energy conservation law, and SVF=1-D_F we obtain :

$$E_{I,BLOCK}=(1-D_F)\ E_{I,REF}$$

Initial irradiance

$$E_{A,BLOCK}=(1-\rho)\ (1-D_F)\ (1+\gamma)\ E_{I,REF}$$

Absorbed SW radiative flux

$$\gamma=D_F*\rho*(1-D_B)/((1-D_B)*(1-D_F)+D_F*(1-\rho))$$

Contribution of multiple reflections
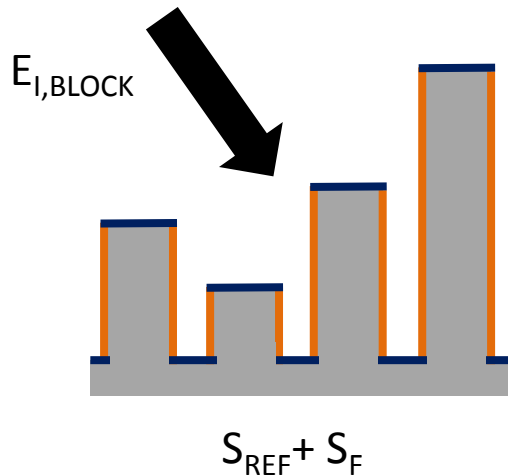
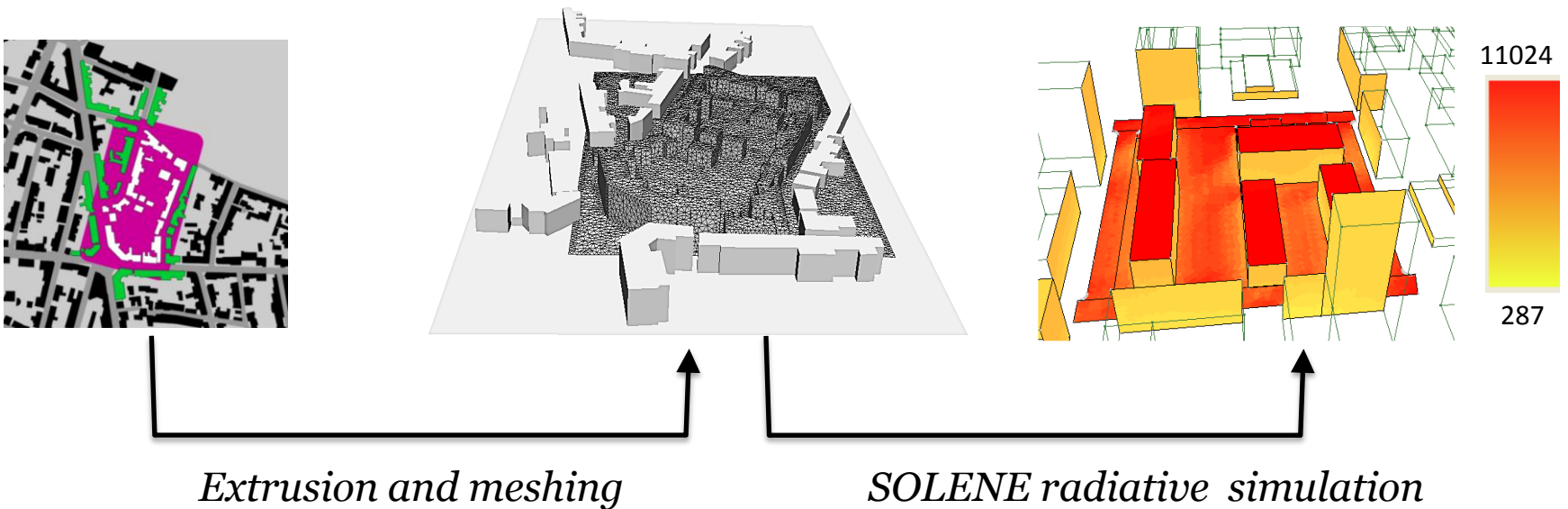**Equivalent albedo**

$$\rho_{BLOCK} = \rho - \gamma + \rho * \gamma$$

2. Validation

Extrusion and meshing   *SOLENE radiative simulation*

Use of SOLENE for irradiance and multiple reflection calculation

III. ANALYTICAL FORMULATION OF SW RADIATION

Formulation based on urban form

SOLENE Calculation

11024

287

D_F D_B SVF → SOLENE → Radiative fluxes and albedo

Comparison

$R^2 = 0.984$

$Y = 1x - 86.3$

Simulations with the SOLENE model
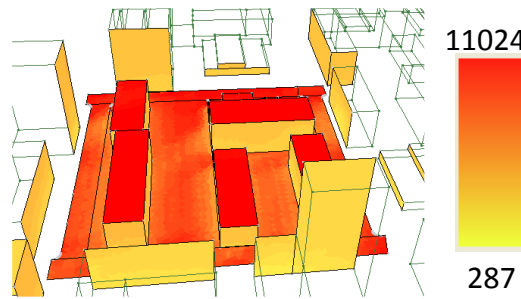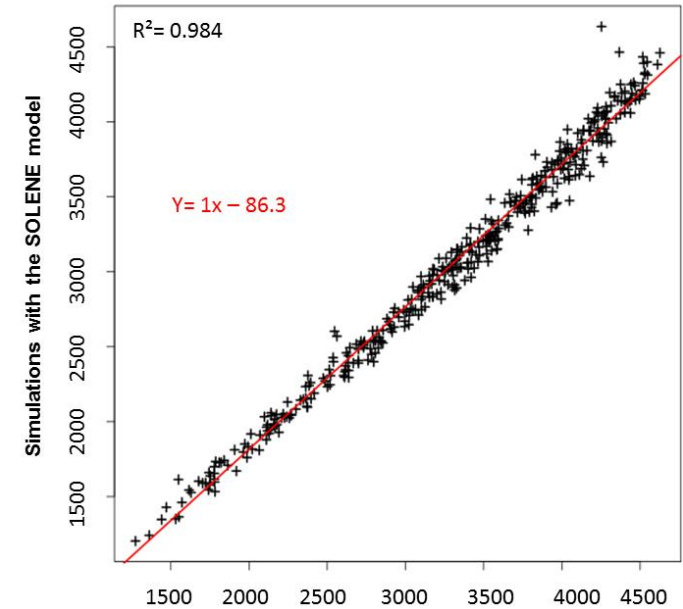
Results obtained with the simplified solar balance model

Example: daily absorbed solar flux with ρ=0.45 – June 21th

3. Vertical variation of fluxes

Initial irradiance (black) and multi reflections (green)
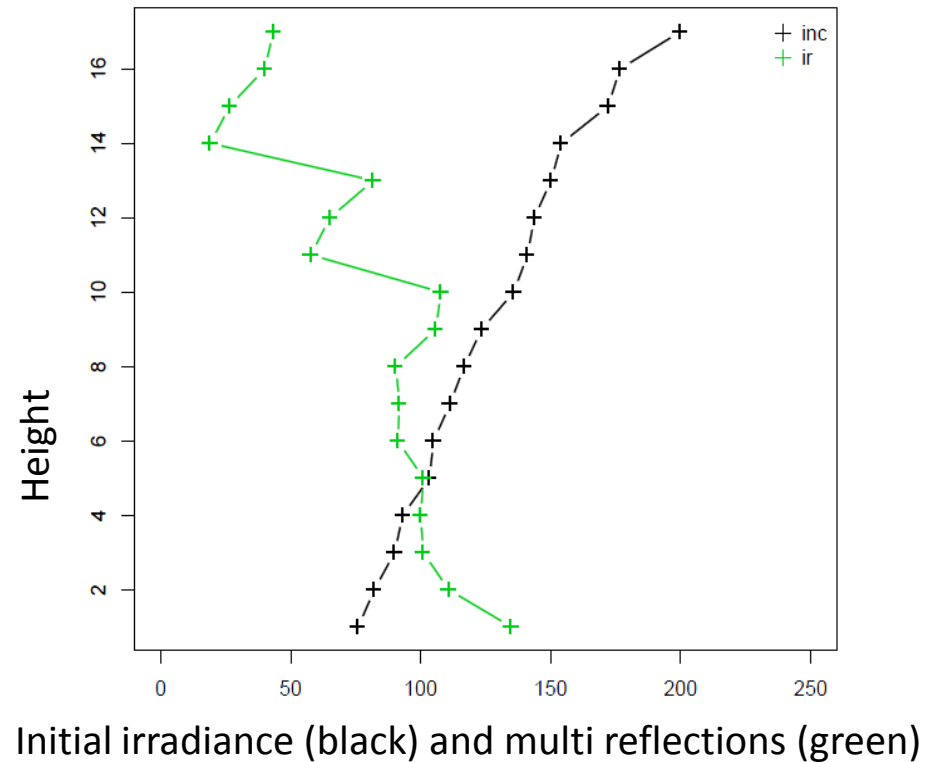
VI. MODEL CONSTRUCTION

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- LW radiative flux also expressed asa function of SVF then D_F

- Exchanges with building expressed from, built density and building types

  See paper presented by J. Bernard « Urban heat island and inertial effects : analyse from field data to spatial analysis »

- Airflow expressed in function on frontal density

A zonal model at the city scale

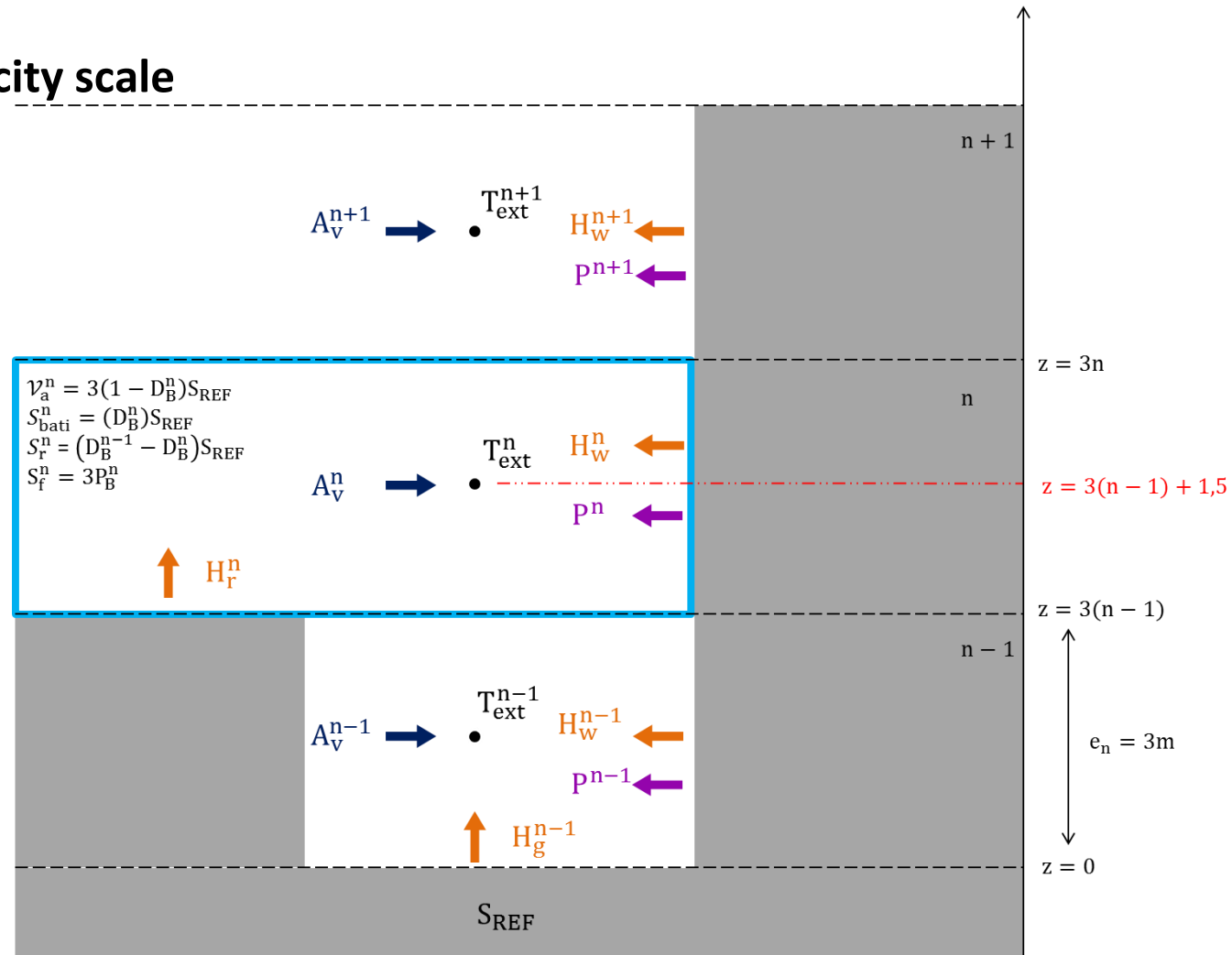Blocks are splitted into layers: creating cells

Airflows, and advective fluxes are calculated between cells

Energy balance is written for each cell to calculate air temperature

$$A_v^{n+1} \rightarrow \bullet\, T_{ext}^{n+1} \quad H_w^{n+1} \leftarrow$$
$$P^{n+1} \leftarrow$$

$n+1$

$z = 3n$

n

$$\mathcal{V}_a^n = 3(1 - D_B^n)S_{REF}$$
$$S_{bati}^n = (D_B^n)S_{REF}$$
$$S_r^n = (D_B^{n-1} - D_B^n)S_{REF}$$
$$S_f^n = 3P_B^n$$

$$A_v^n \rightarrow \bullet\, T_{ext}^n \quad H_w^n \leftarrow$$
$$P^n \leftarrow$$

$z = 3(n-1) + 1{,}5$

$$\uparrow H_r^n$$

$z = 3(n-1)$

$n-1$

$$A_v^{n-1} \rightarrow \bullet\, T_{ext}^{n-1} \quad H_w^{n-1} \leftarrow$$
$$P^{n-1} \leftarrow$$

$e_n = 3m$

$$\uparrow H_g^{n-1}$$

$z = 0$

$$S_{REF}$$

V. CONCLUSIONS

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- A radiative model at the block scale based on morphology that can be used in mesoscale climate models (-> ARPS-VUC)
  - Validated for homogeneous reflectivities
  - Must be studied for heteogeneous reflectivities

- A urban climate model based on zonal models methods and GIS
  - In progress

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