« New developments on the radiative scheme, energetic balance and air flow in TEB canyons with trees »

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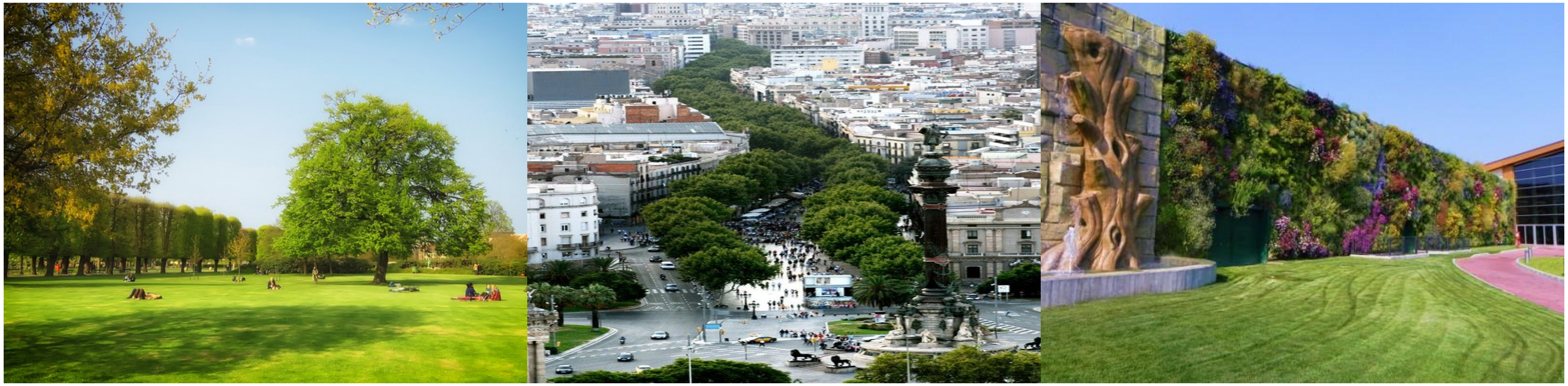
Downscaling : representation of the urban landscape heterogeneity

UHI migitation : urban planning strategies assessment

Cooling power of greening strategies ?

Associated water resources ?

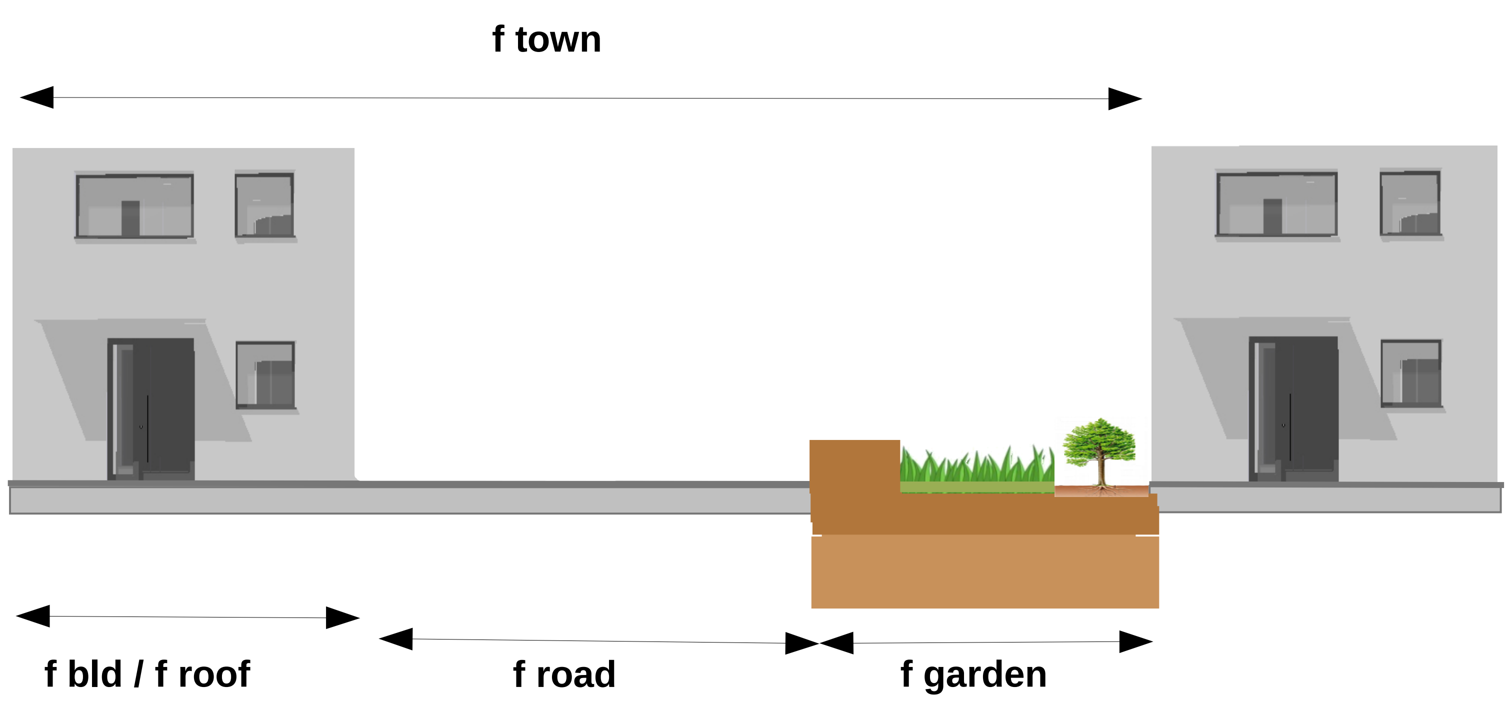
Thermal comfort of inhabitants ?



Concept of TEB (Lemonsu et al., 2012)

Cover fraction approach (Masson, 2000)

« Big Leaf » approach: one composite layer of urban vegetation



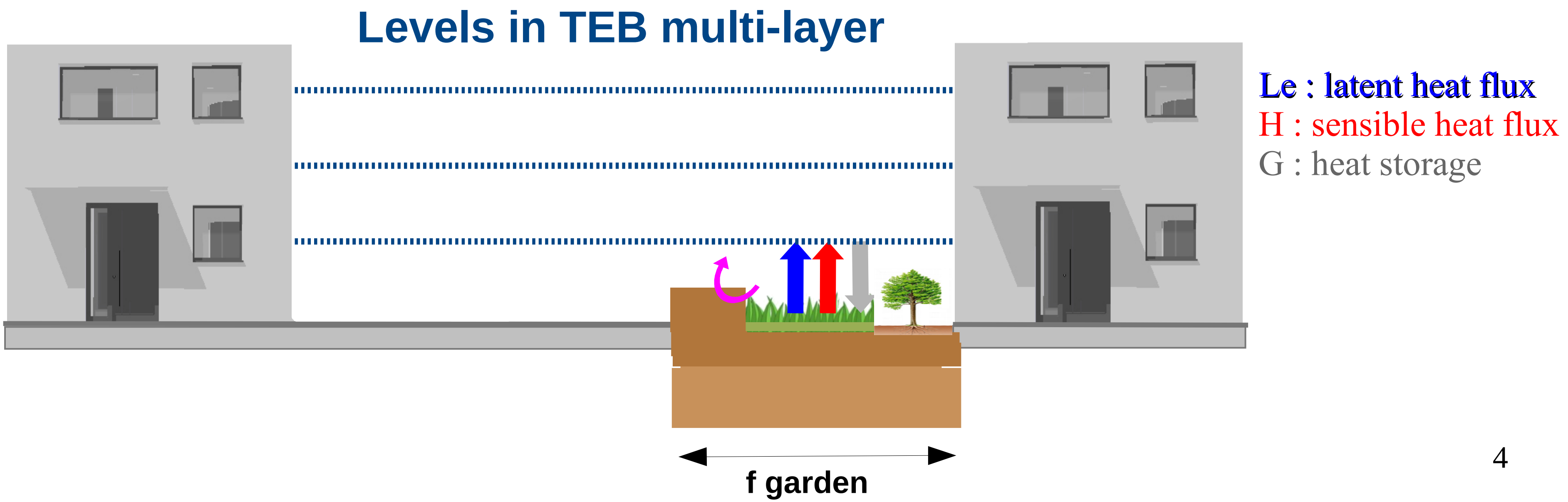
Concept of TEB (Lemonsu et al., 2012)

No differentiated strata:

- no shading effect of trees

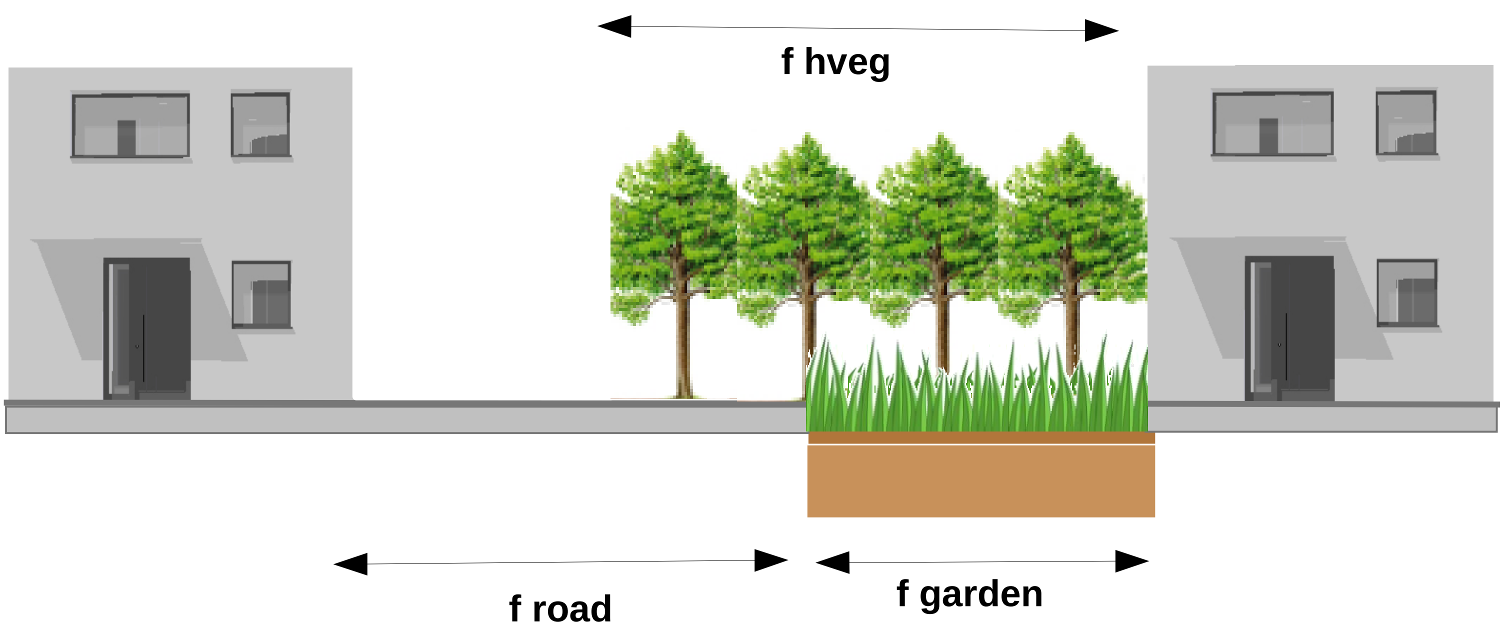
H and LE fluxes from urban vegetation assigned to the surface:

- no impact on the vertical gradients of T, Q
- no impact on the air flow



New definitions / parameters required for urban trees representation in TEB

Real tree layer : high vegetation can overlay and exceed natural ground fractions



« Radiative scheme, energetic balance and air flow in TEB canyons with trees »

Input parameters related to the high vegetation

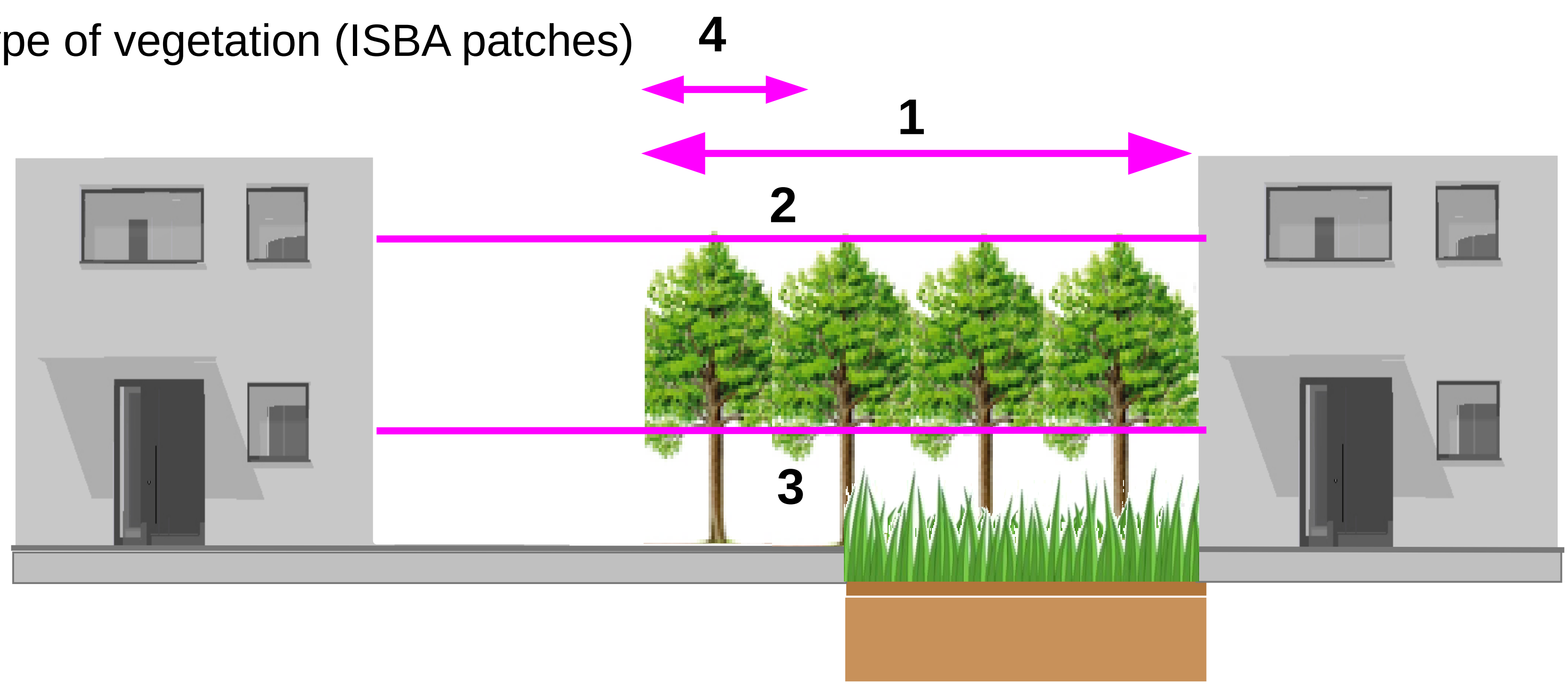
- cover fraction

- tree height

- trunk height

- crown width

- type of vegetation (ISBA patches)

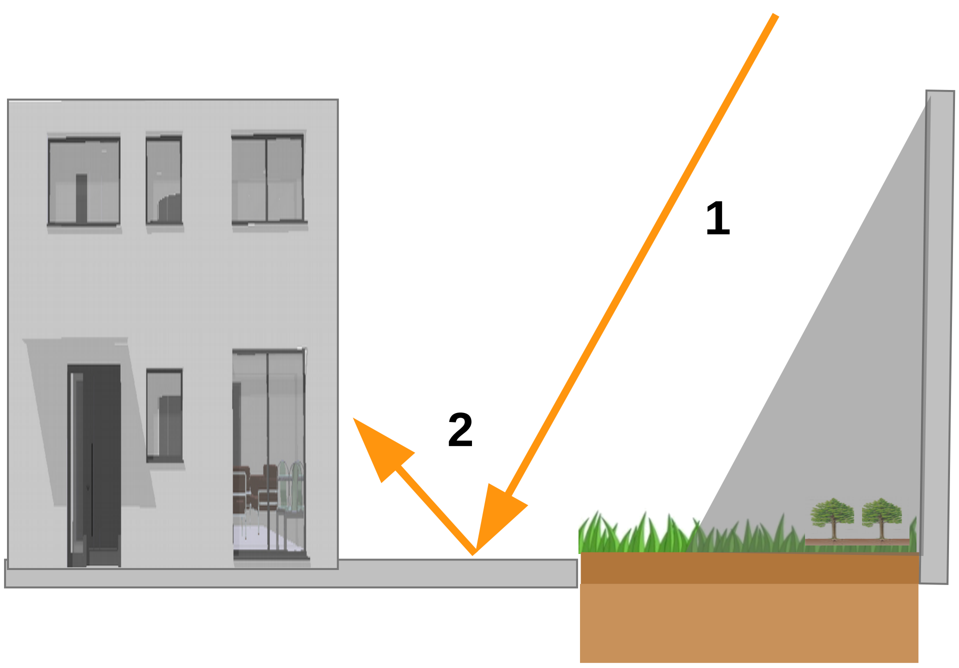


« Radiative scheme, energetic balance and air flow in TEB canyons with trees »

Resolving radiative balance by urban surface in TEB : identifying involved processes

1 Direct solar radiation received by each surface
=> geometric approach function of zenith angle and canyon geometry

2 Diffuse solar radiation received by each surface and infinite reflections
=> geometric approach based on Form Factors method (a unique form factor per interaction)



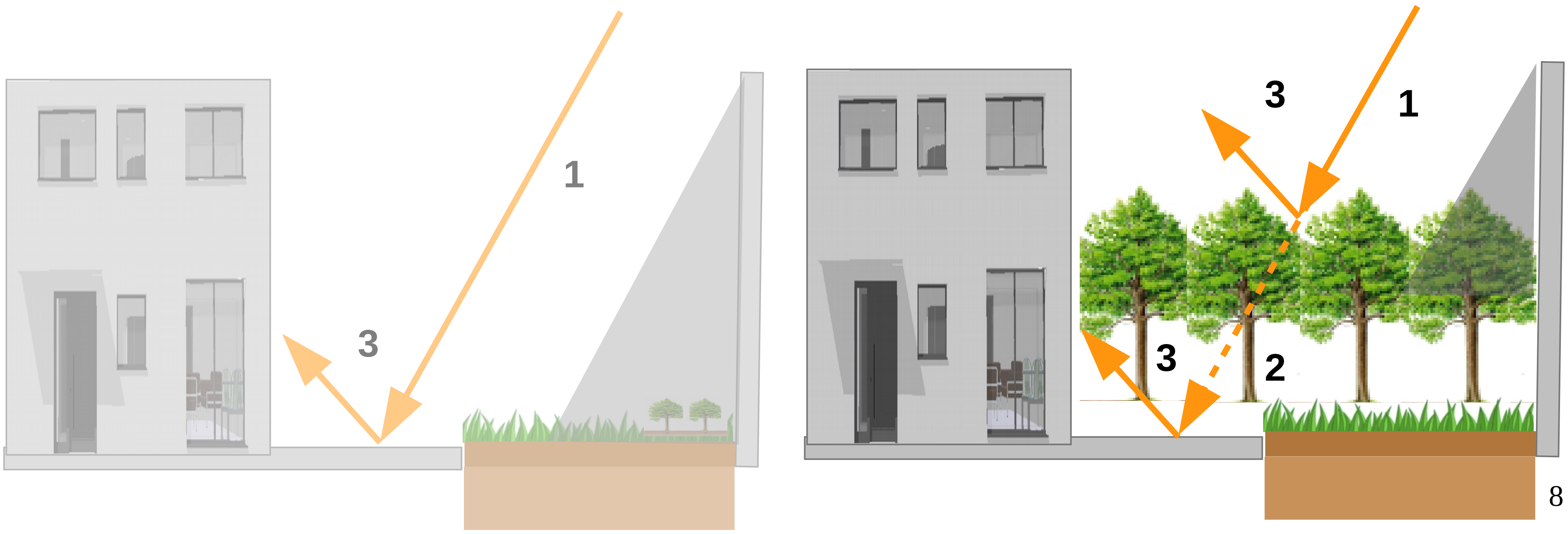
« Radiative scheme, energetic balance and air flow in TEB canyons with trees »

Resolving radiative balance by urban surface in TEB : identifying involved processes

1 Direct solar radiation received by HIGH VEGETATION
=> geometric approach function of zenith angle, canyon geometry and top of tree crown

2 Part of direct solar radiation transmitted by HIGH VEGETATION to WALLS and GROUND
=> Beer – Lambert attenuation

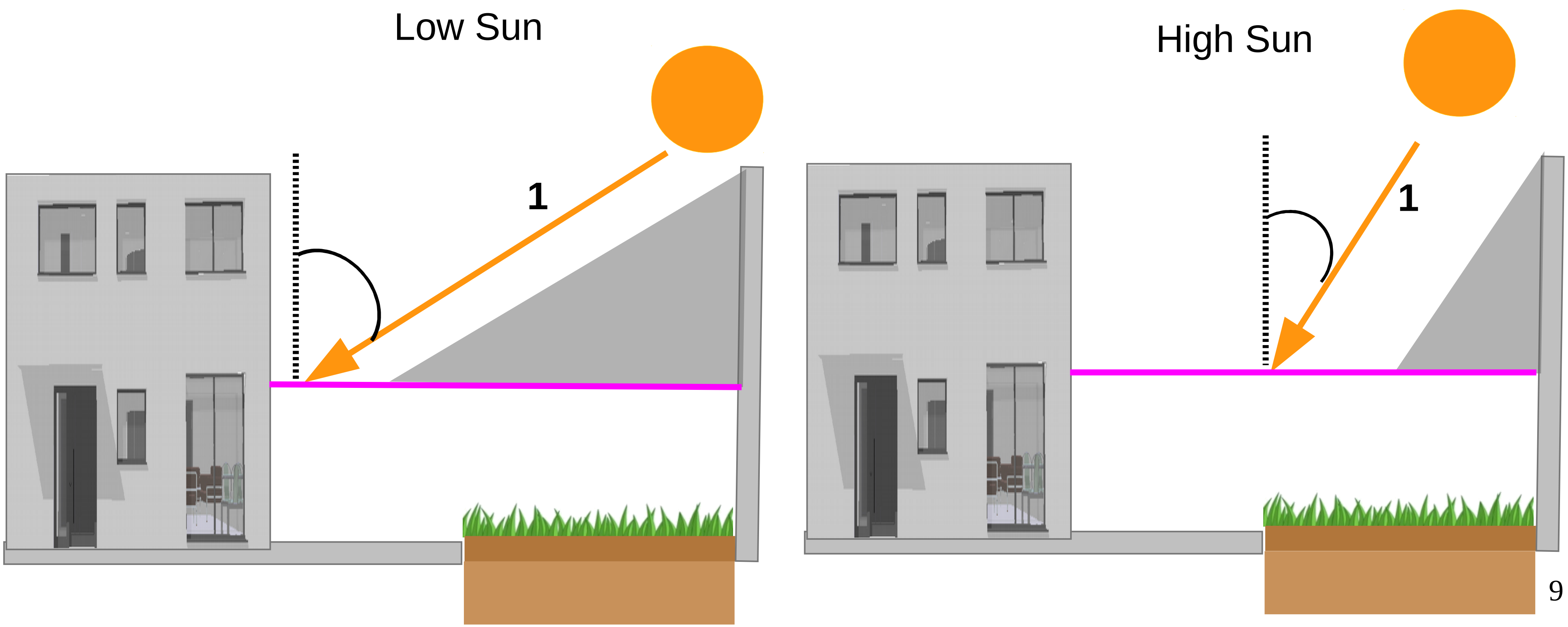
3 Diffuse solar radiation received by each surface and infinite reflections
=> geometric approach based on Form Factors method and transmissivity terms



Resolving radiative balance by urban surface in TEB : illustrated examples

Direct solar radiation received by HIGH VEGETATION
=> geometric approach function of zenith angle, canyon geometry and top of tree crown

Shading of buildings on high vegetation



Resolving radiative balance by urban surface in TEB : illustrated examples

Part of direct solar radiation transmitted by HIGH VEGETATION to WALLS and GROUND

=> Beer – Lambert attenuation

Shading of high vegetation on walls and ground

Transmissivity term τ (from Lee & Park, 2008) :

$$\tau_{\text{HIGH VEG / GROUND OR WALL}} = \exp(-k \times LAI)$$

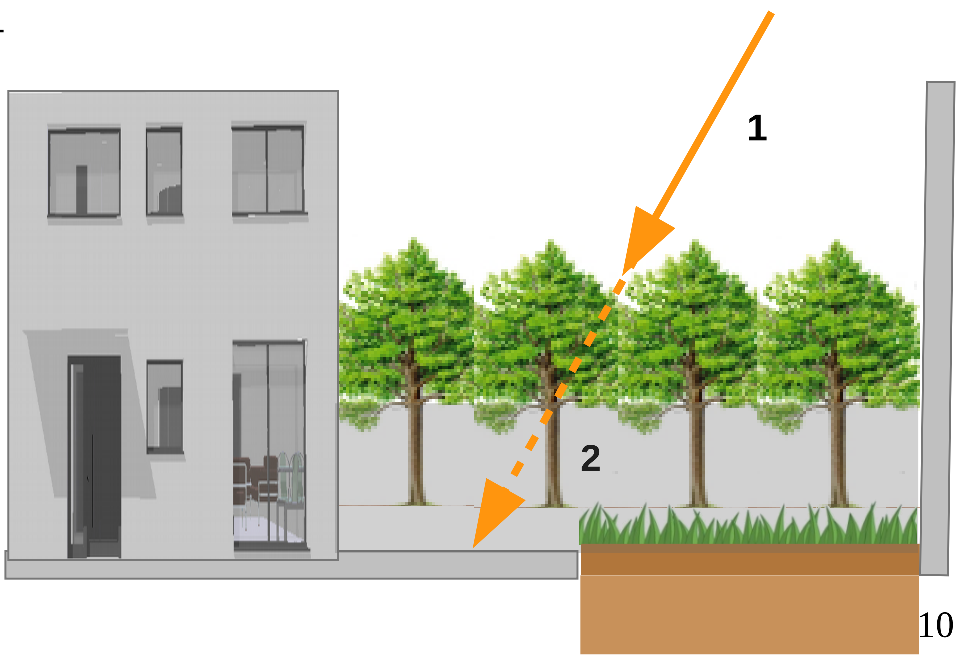
Extinction coefficient k (= 0,5 in TEB)

Homogeneous foliage distribution

Leaf Area Index ($m^2\ m^{-2}$)

from sky to ground :

all foliage crossed by solar rays



Resolving radiative balance by urban surface in TEB : illustrated examples

Part of direct solar radiation - received and transmitted by HIGH VEGETATION
- received by ROAD
- reflected from ROAD to WALL1

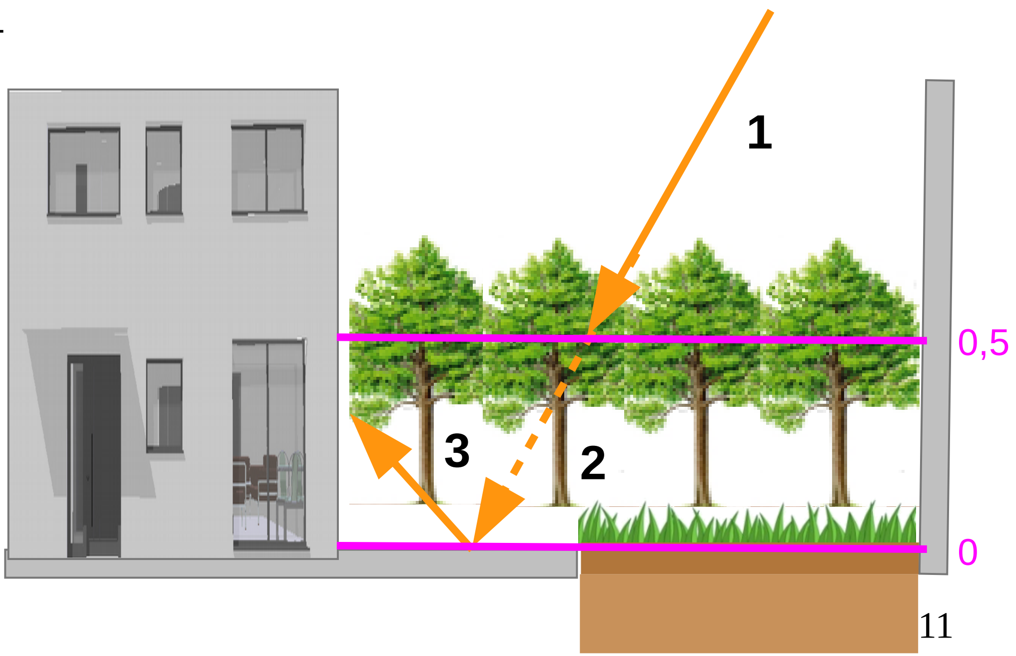
Adequate HV transmissivity, function of involved surfaces

<u>Transmissivity term τ (from Lee & Park, 2008) :</u>

$$\tau_{\text{ROAD / WALL 1}} = \exp(-k \times LAD)$$

Extinction coefficient k (= 0,5 in TEB)

Leaf Area Density (m^3 m^{-2})
from ground to wall :
foliage density crossed by rays
included in 0 – 0,5 building height zone



Evaluation of TEB with trees : radiative budget

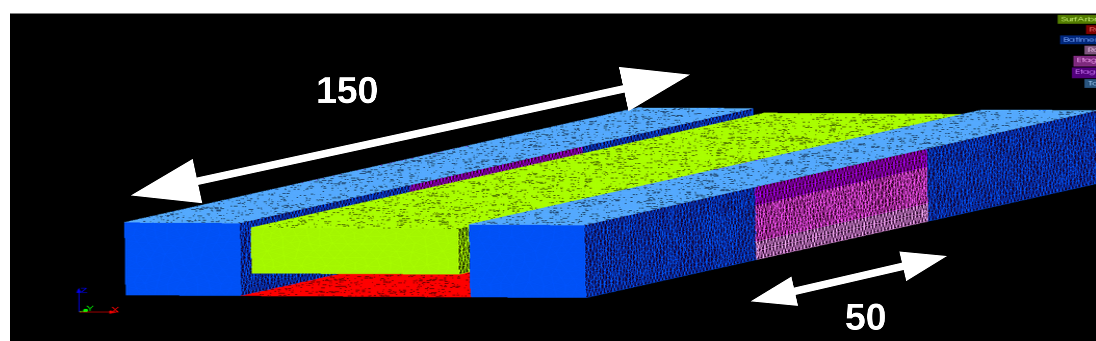
Objectives :
How to appreciate quality of radiation absorption simulation in TEB ?
How to identify configurations for which TEB assumptions can be applied or not ?

Main issue :
Complete experimental data for various urban configurations

Strategy :
Fine scale model of enlightenment **SOLENE** (CERMA lab., Nantes, France) as reference model

=> control of configurations

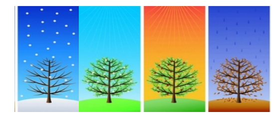
=> numerous ideal cases tested



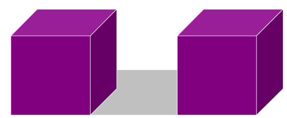
Evaluation of TEB with trees : radiative budget

Simulations design of one day (24 hours) :

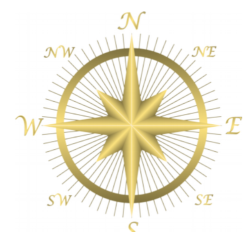
4 seasons : winter – spring – summer- autumn



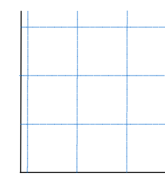
3 aspect ratios h/w : 0,5 - 1 – 2

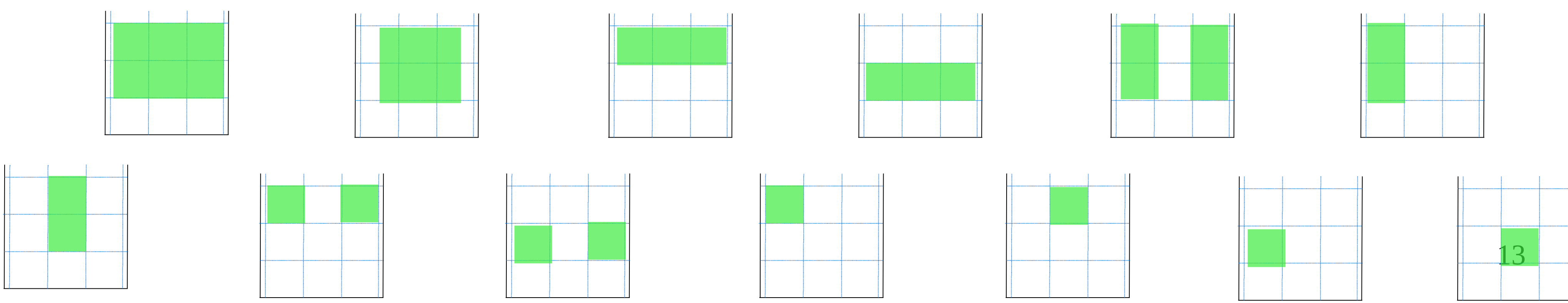


4 canyon orientations : 0° - 45° - 90° - 135°



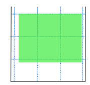
13 extreme vegetation layouts (+ control cases without vegetation) :





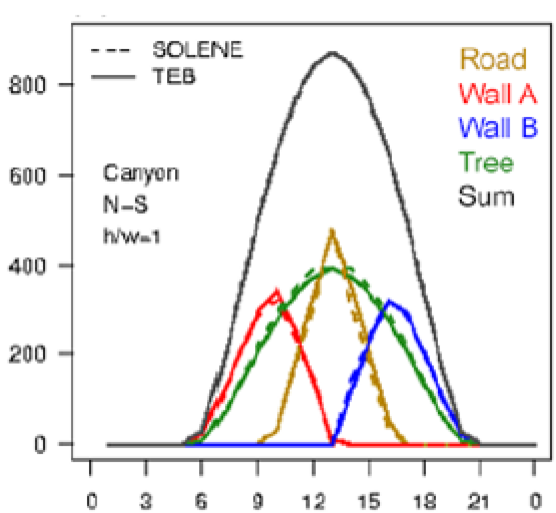
Evaluation of TEB with trees : radiative budget

Extremely vegetated canyon

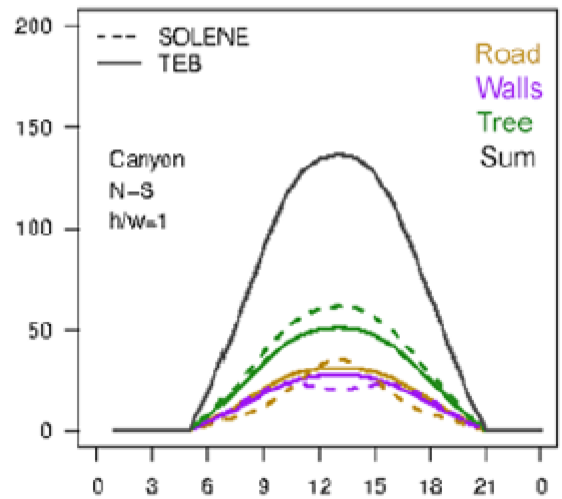


h/w = 1 - orientation 0° - summer day

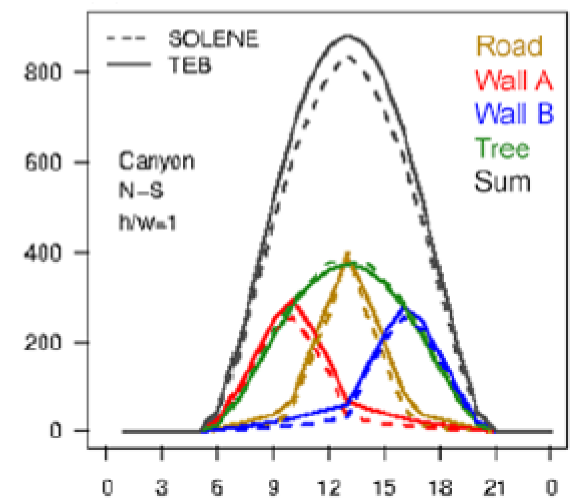
Received direct SR (W m^{-2})



Received diffuse SR (W m^{-2})



Absorbed total SR (W m^{-2})



Redon *et al.*, 2017

Surface / Abs SR flux	Mean Absolute Difference	Mean Absolute Percentage Difference	Bias
	W m^{-2}	%	W m^{-2}
Road	12.97	29	+11.90
Walls	10.11	16	+10.11
Tree	4.22	5	-4.11

Infra-Red exchanges

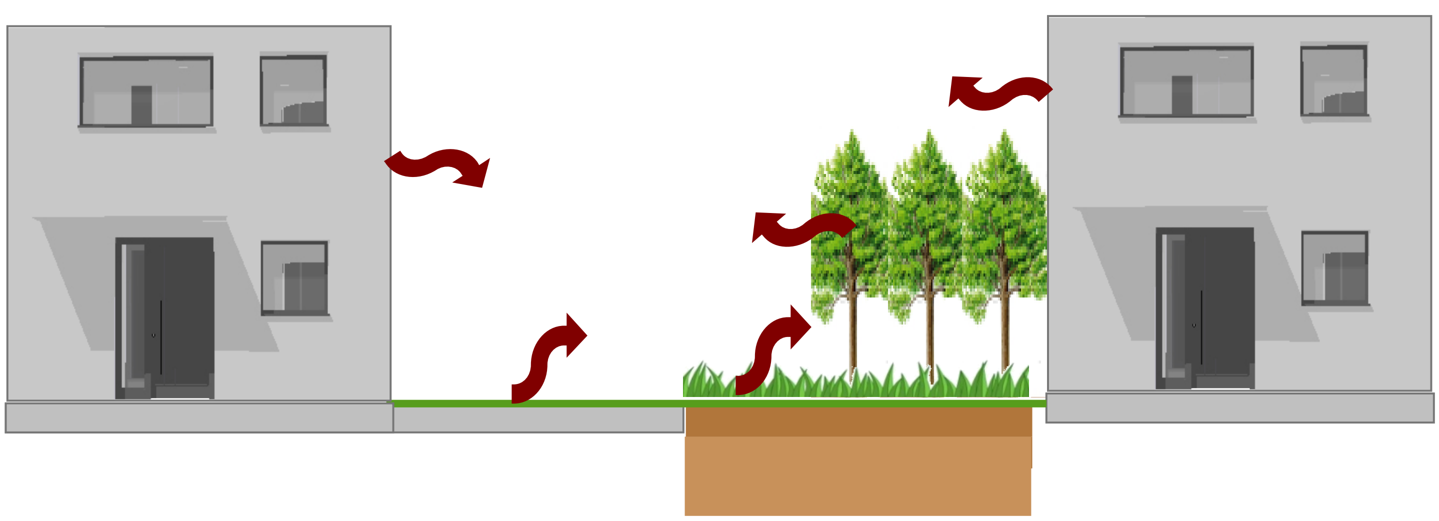
Based on a linear approximation of the Stefan-Boltzmann law

High vegetation can interact with all other facets of the canyon

IR exchanges are constrained by validated parameters of the solar radiative transfer:

- same view factors

- same transmissivity terms



Energy budget and microclimate

"Big Leaf" approach with aggregated S and L fluxes

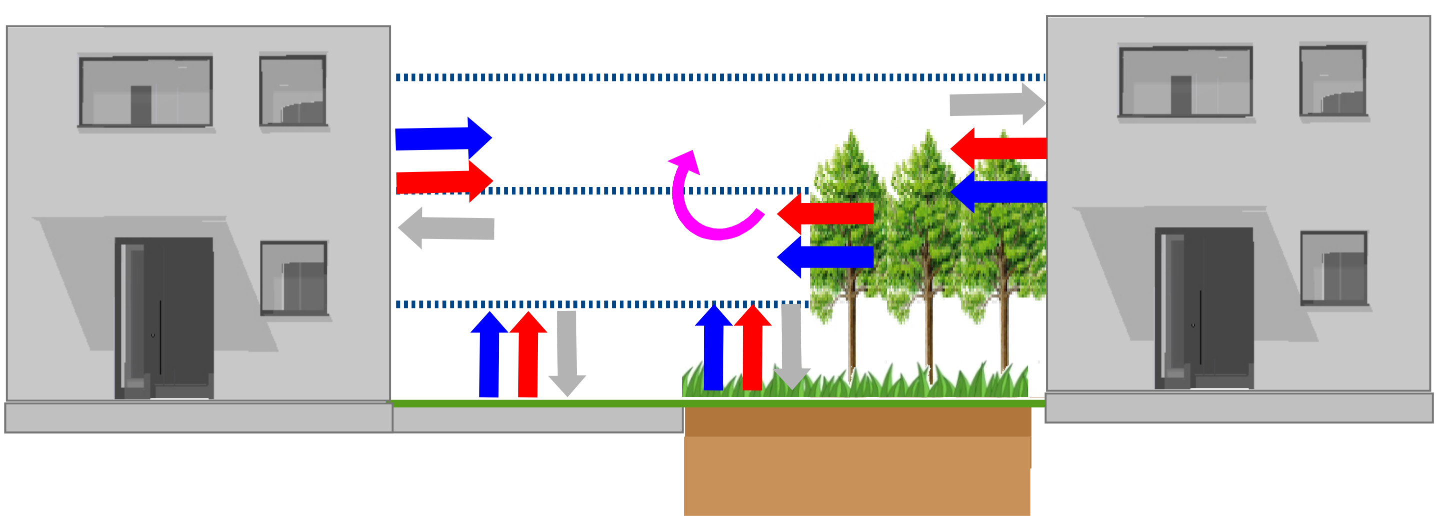
Disaggregation of computed H and LE fluxes between GARDEN and HVEG

Contributions from HVEG are vertically distributed according to the % of LAD profile

and levels of the TEB Multi-Layer (Hamdi & Masson, 2008; Masson & Seity, 2009)

Alteration of the microclimate by trees at realistic levels

CANOPY levels



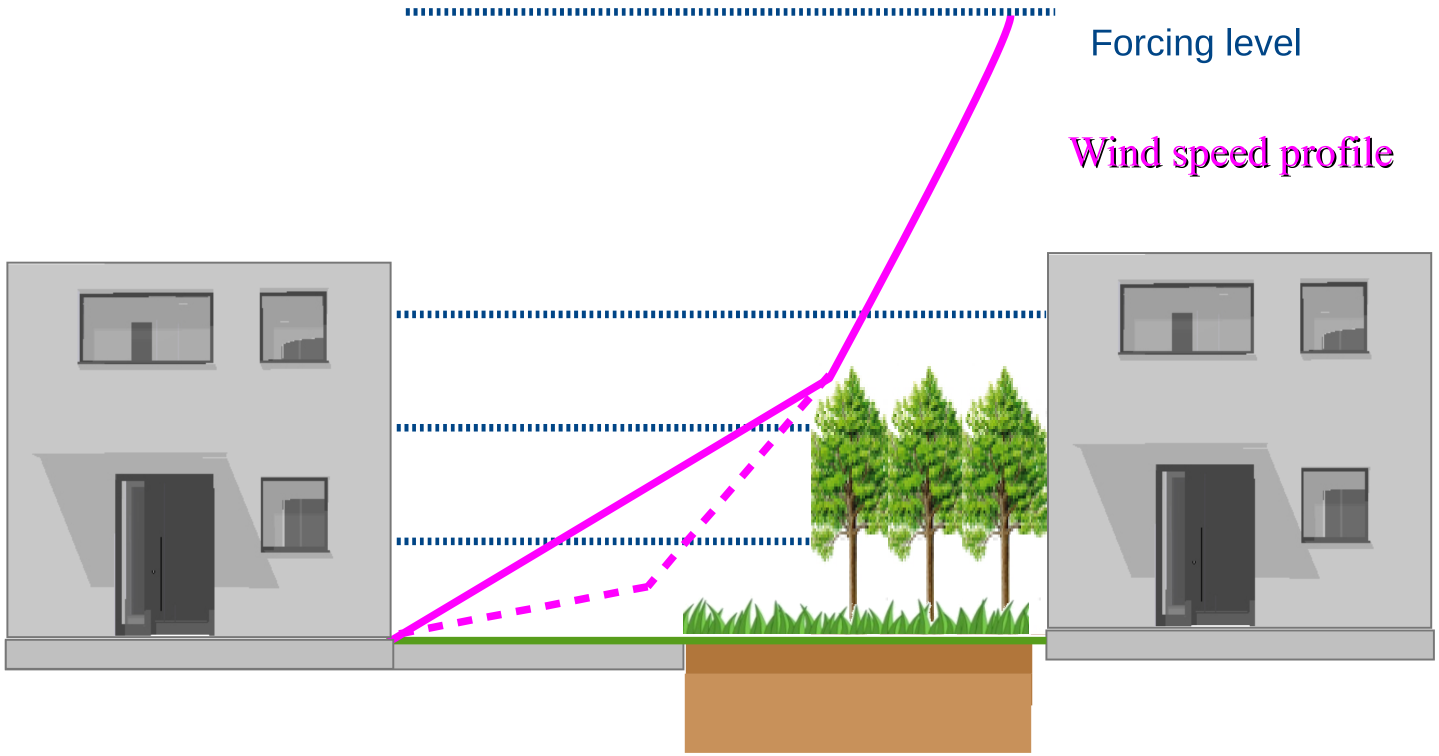
Le : latent heat flux
H : sensible heat flux
G : heat storage

Impact of trees on air flow:

A frontal area density profile derived from the LAD profile (adapted from Aumond et al., 2013)

A specific drag coefficient for high vegetation (default value of 0.20)

Change in the height of inflection point



« Radiative scheme, energetic balance and air flow in TEB canyons with trees »

Context – TEB with trees – Radiative balance – Results – Energy budget – Air flow

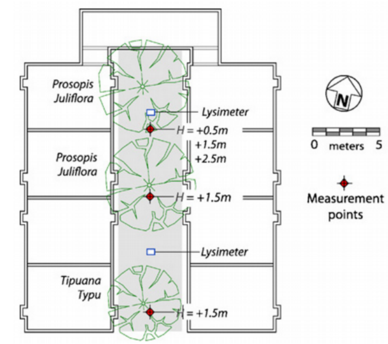
Conclusions :

Radiative transfer (interception, shading effects) and IR exchanges with trees

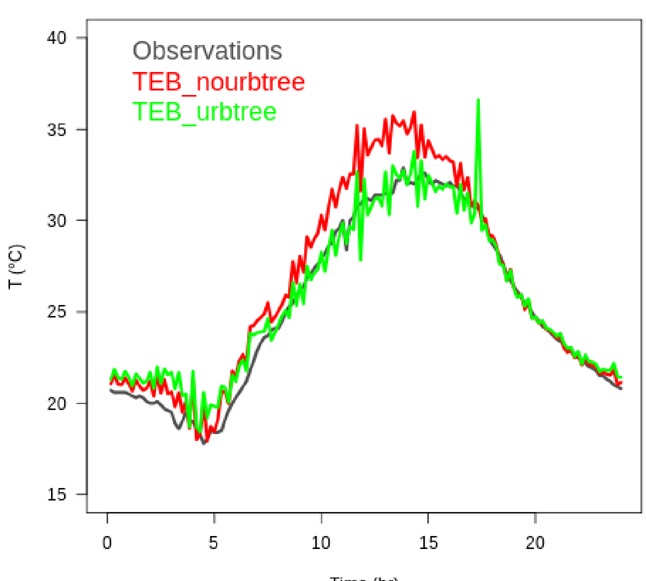
Turbulence and microclimate altered by trees at realistic levels

Aerodynamic effect of trees

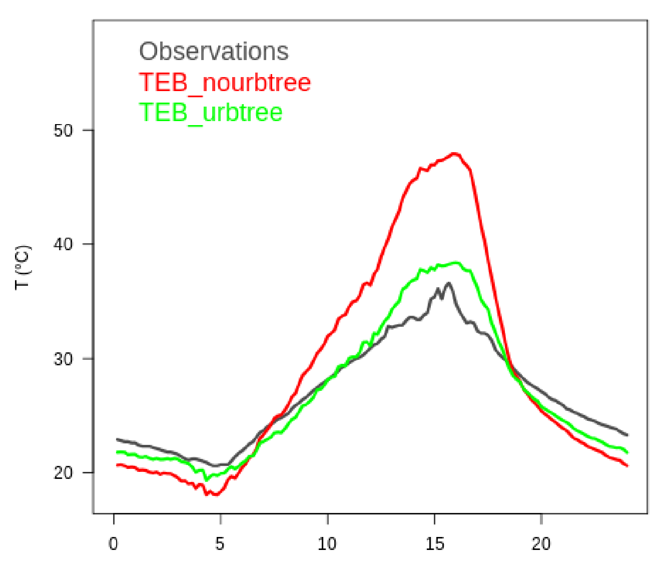
Experimental case at Sde Boker, Israël



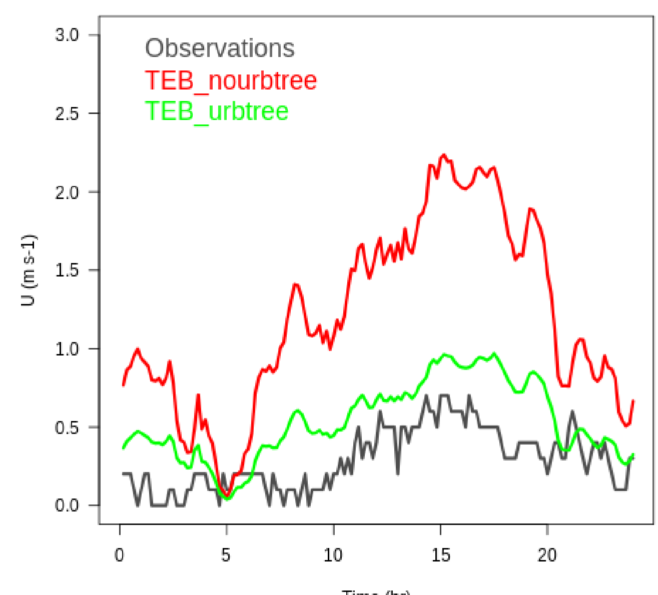
Air temperature



Western wall temperature



Wind speed



Building Energy Model
(Bueno et al., 2011)
(Schoëtter et al., submitted)

Canopy (SBL model)
(Hamdi & Masson, 2008)

Town Energy Balance
(Masson, 2000)

Hydro
(Lafaille et al., submitted)

Urban Vegetation
- bare soil and low vegetation
(Lemonsu et al., 2012)
- high vegetation
(Redon et al., 2017)
- green rooofs
(De Munck et al., 2013)

THANK YOU FOR YOUR ATTENTION

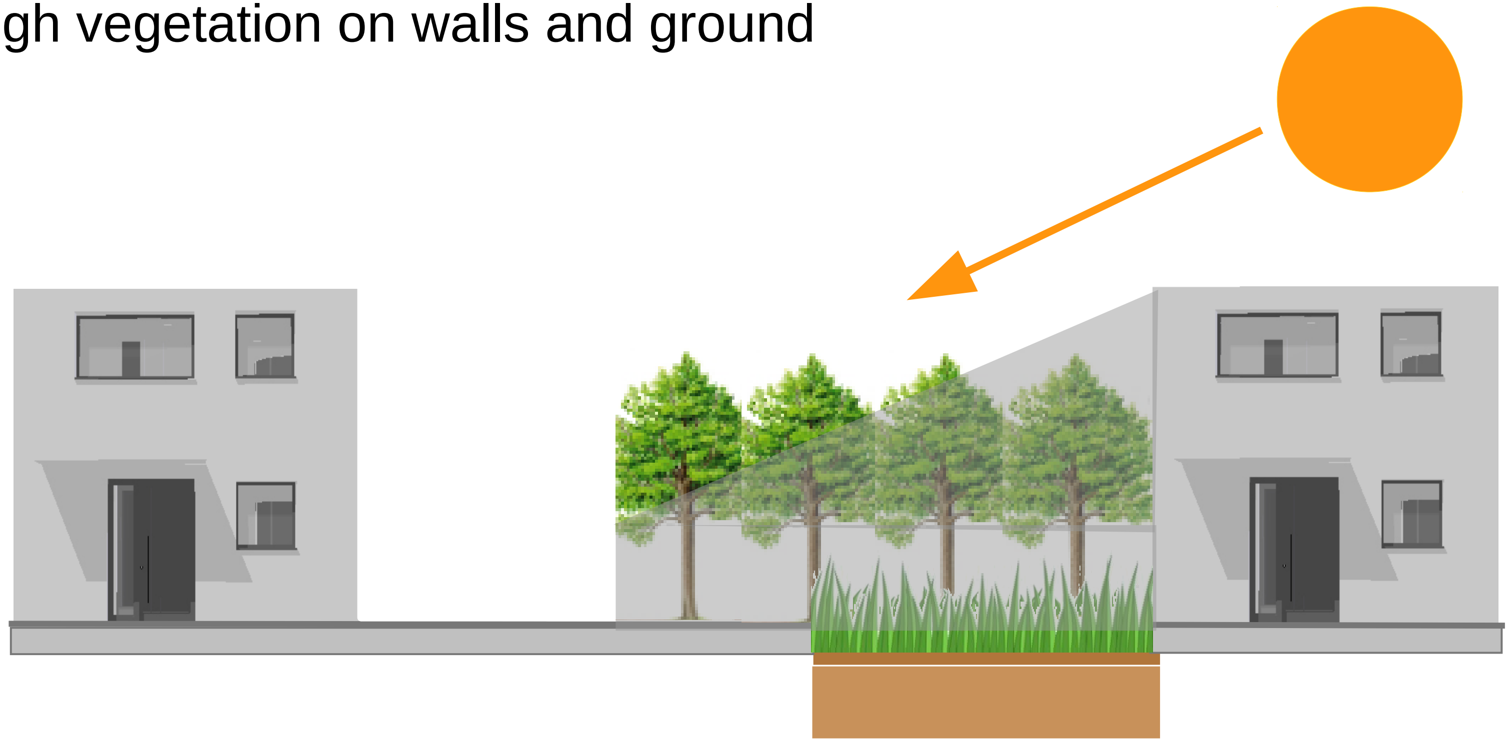
Email : emilie.redon@meteo.fr

Sources of tre image
http://encyclopedie_universelle.fracademic.com/1182/ARBRE

New definitions / parameters required for urban trees representation in TEB

Real tree layer : high vegetation can overlay and exceed natural ground fractions

Shading effects :
- buildings on high vegetation
- high vegetation on walls and ground

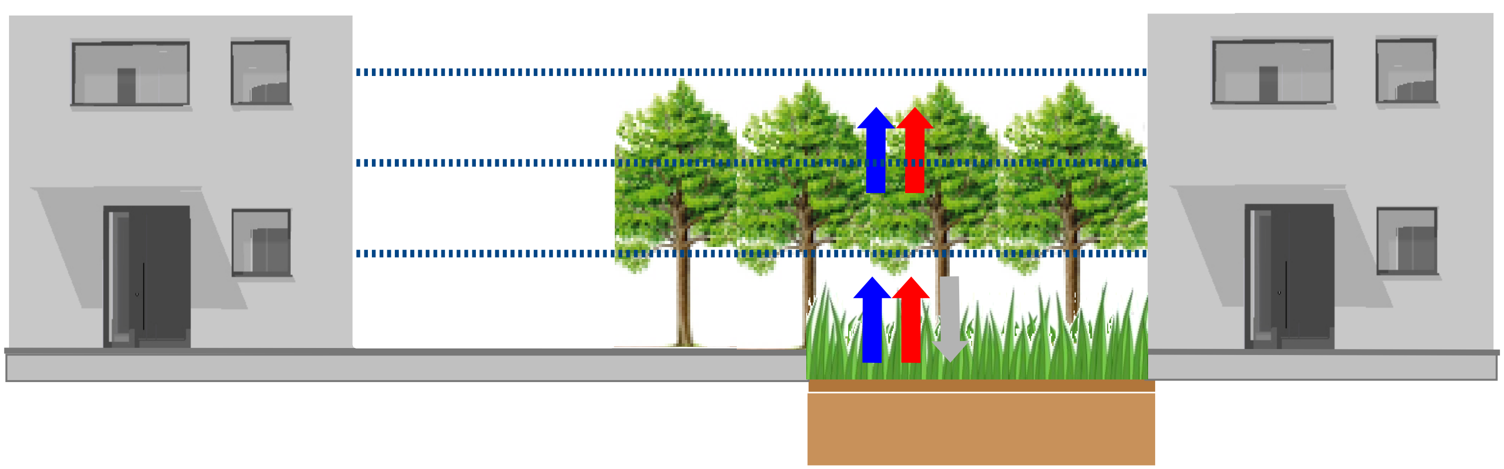


New definitions / parameters required for urban trees representation in TEB

Real tree layer : high vegetation can overlay and exceed natural ground fractions

Shading effects :
- buildings on high vegetation
- high vegetation on walls and ground

Sensible and latent heat fluxes distributed with respect to their vertical gradient

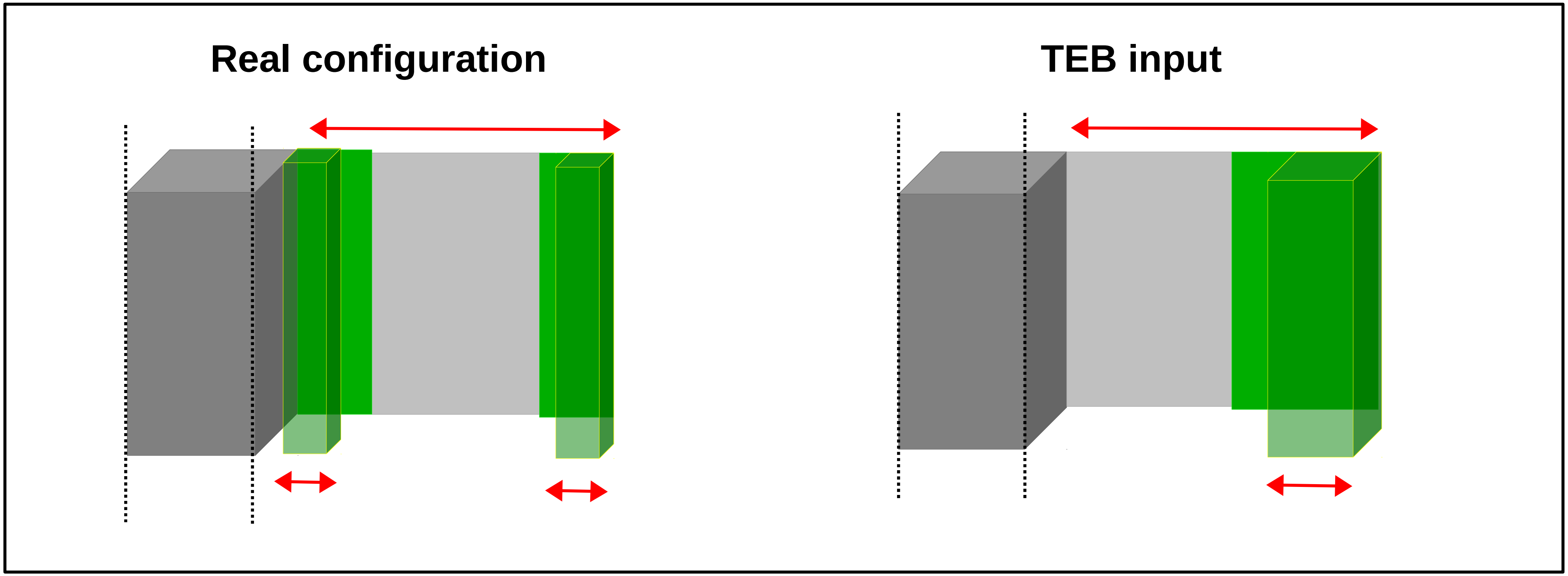


How high vegetation fraction is computed ?

High vegetation fraction is depending on :

- 2D extension (sum of crown widths)

View from above the street



How high vegetation fraction is computed ?

High vegetation fraction is depending on :

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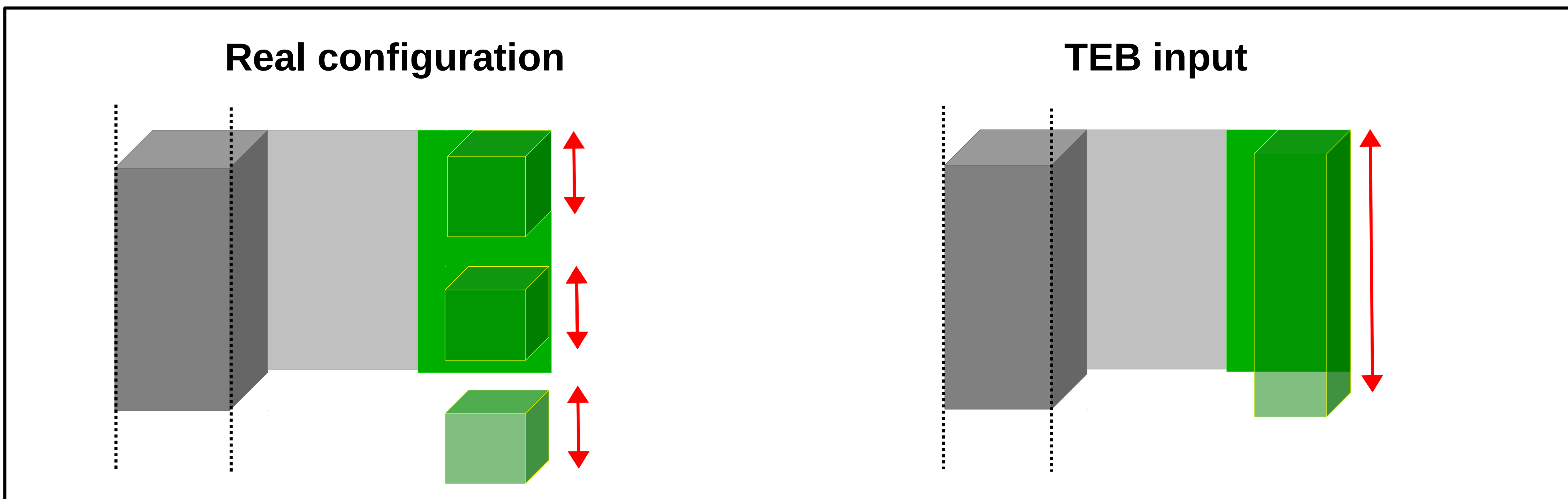
- along street distribution (relating to potential gaps in tree lines)

View from above the street

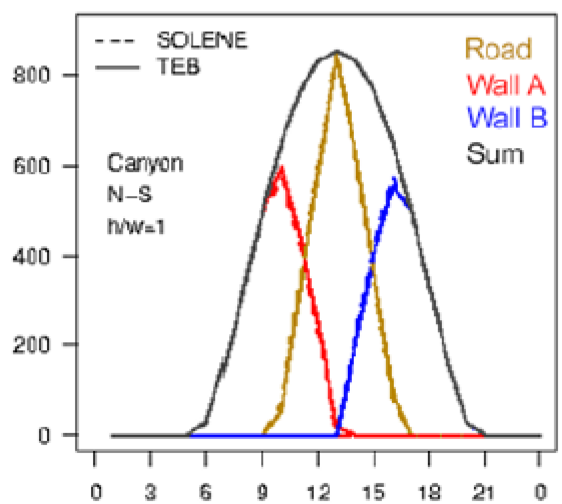


Evaluation of TEB with trees : radiative budget

Canyon without vegetation (control case)

h/w = 1 - orientation 0° - summer day

Received direct SR (W m^{-2})



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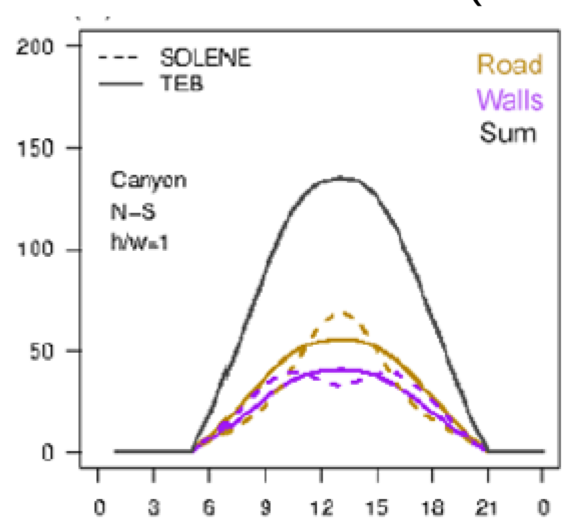
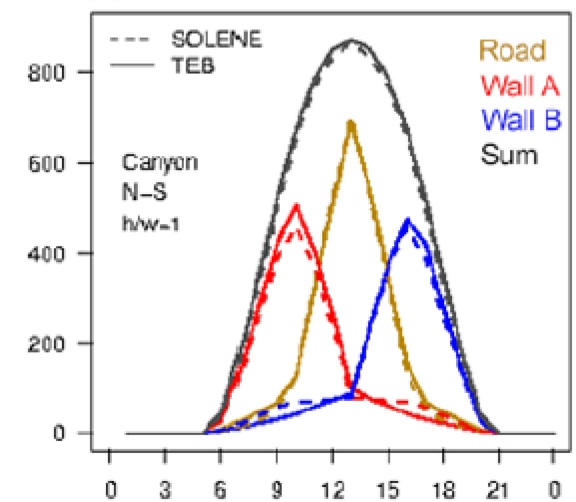


Absorbed total SR (W m^{-2})



Redon *et al.*, 2017

Surface / Abs SR flux	Mean Absolute Difference	Mean Absolute Percentage Difference	Bias
	W m^{-2}	%	W m^{-2}
Road	8.59	4	4.84
Walls	3.29	3	2.83

How high vegetation fraction is computed ?

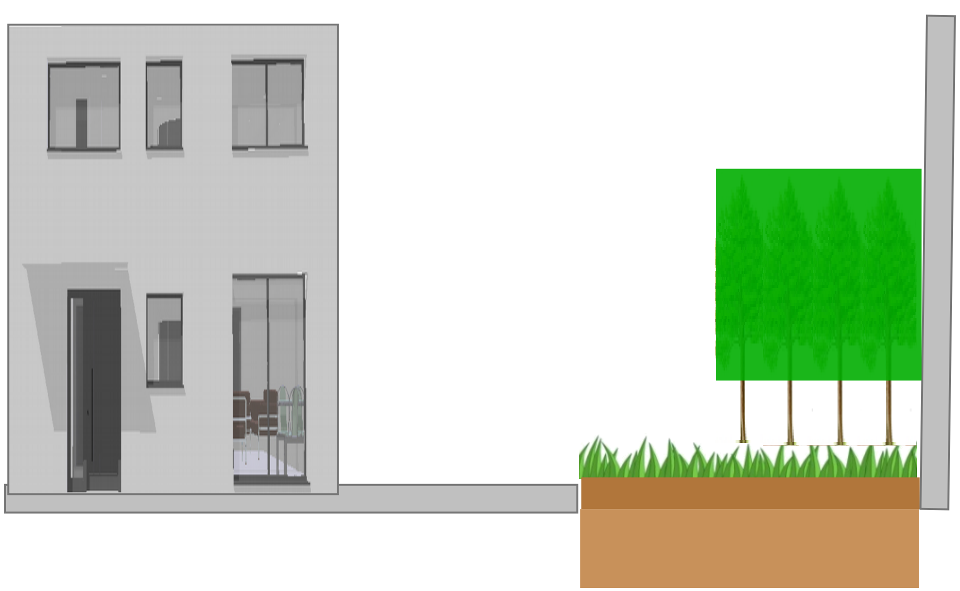
High vegetation fraction is depending on :

- 2D extension (sum of crown widths)

- along street distribution (relating to potential gaps in tree lines)

This value is homogeneously applied on canyon width (without spatialization)

Real configuration



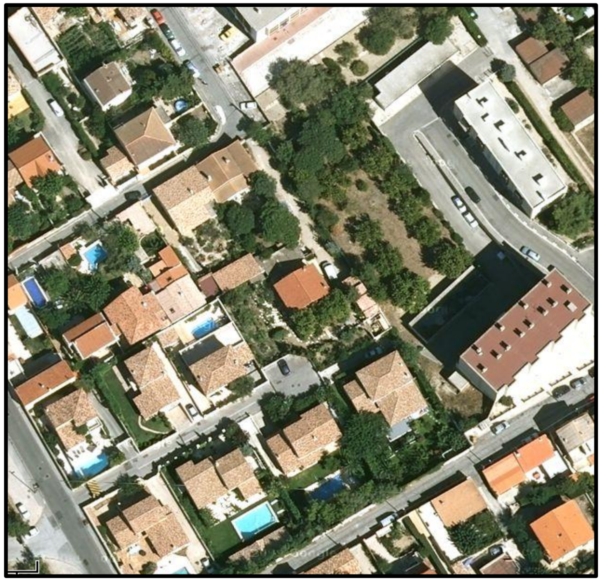
TEB input

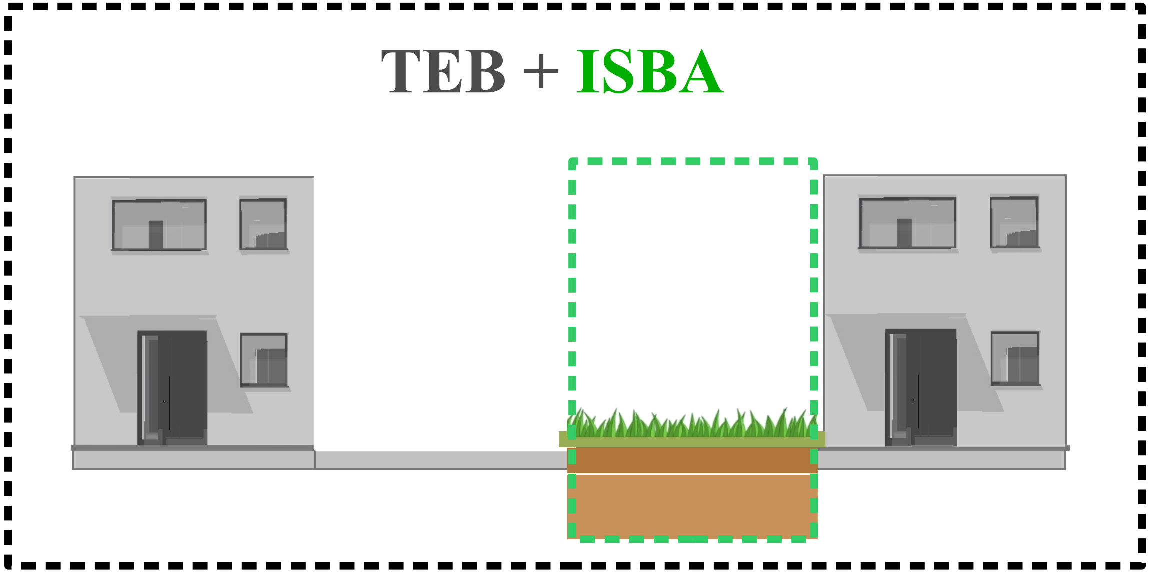
UHI migitation : urban planning strategies assessment

Interactions within urban canopy between impervious surfaces (TEB) and vegetation (ISBA)

ISBA : Soil – Biosphere – Atmosphere Interactions (SVAT type)

TEB : Town Energy Balance, a urban canopy model



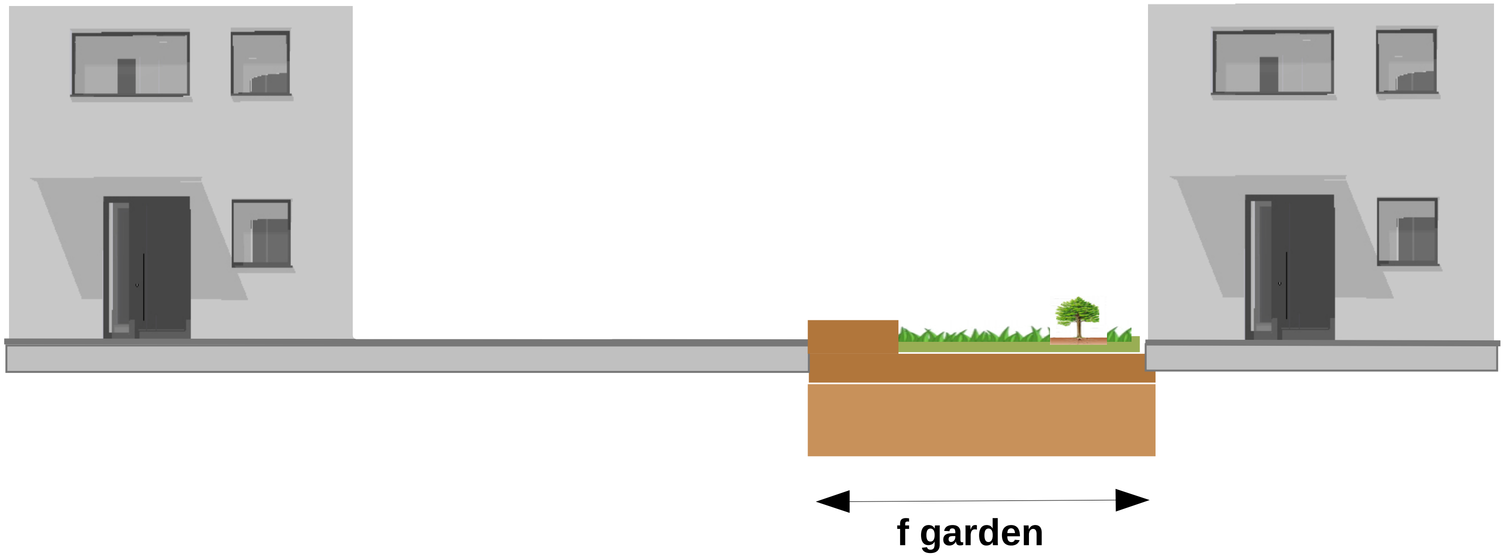


Concept of TEB (Lemonsu et al., 2012)

Before new implementations concerning urban trees :

'Garden' fraction includes 3 sub-fractions :

bare soil - low vegetation (herbaceous) - high vegetation (trees)

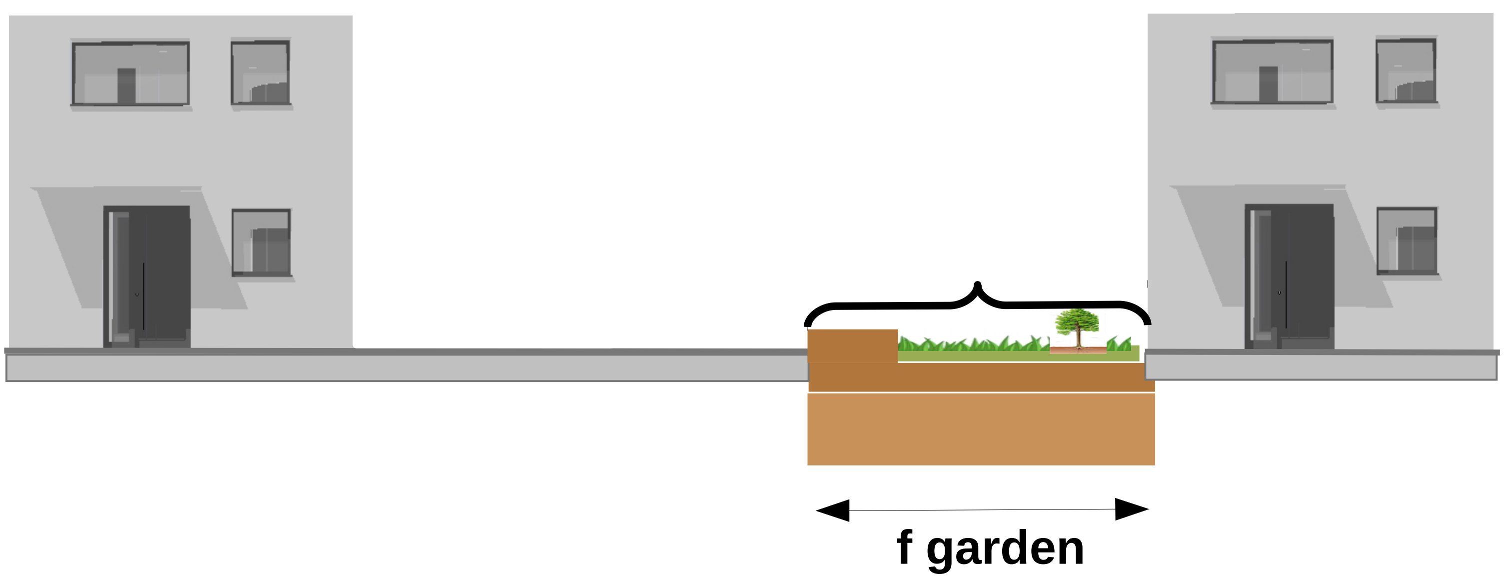


Concept of TEB (Lemonsu et al., 2012)

<u>Before new implementations concerning urban trees :</u>

Physiological parameters averaged on garden fraction

(ex : stomatal conductance, ...)



Concept of TEB (Lemonsu et al., 2012)

<u>Before new implementations concerning urban trees :</u>

All sub-fractions in only one composite surface layer (no differentiated strata)