« Street trees in the urban canopy model TEB »

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ICUC9

METEO FRANCE

UHI migitation : urban planning strategies assessment

Cooling power of greening strategies ?

Associated water resources ?

Thermal comfort of inhabitants ?

+ public parks

+ private gardens

+ street trees

+ soil, subsoil, sewer network

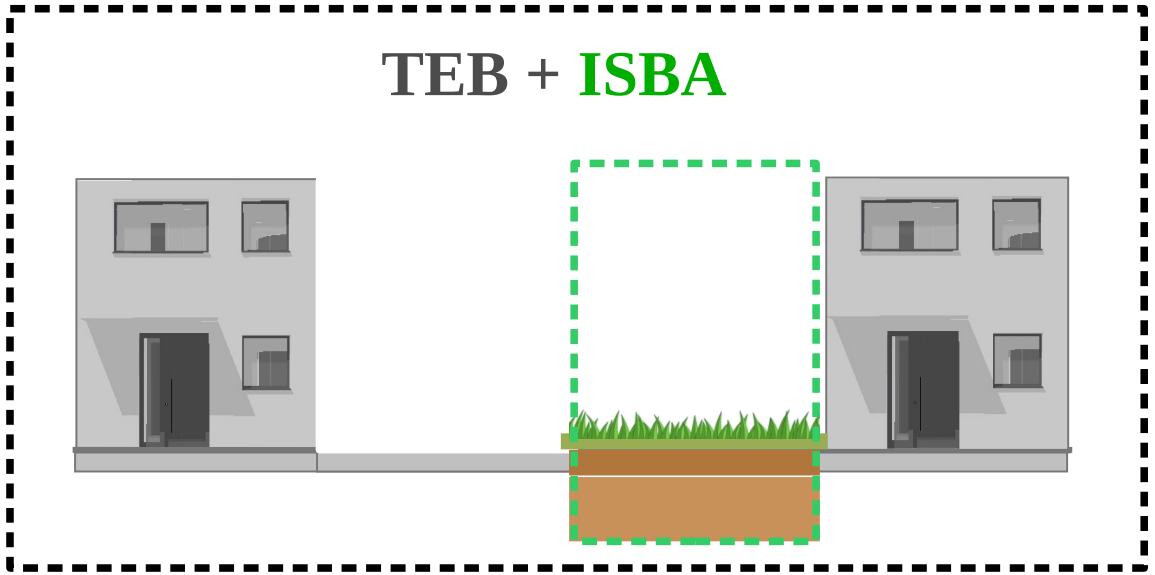
+watering

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

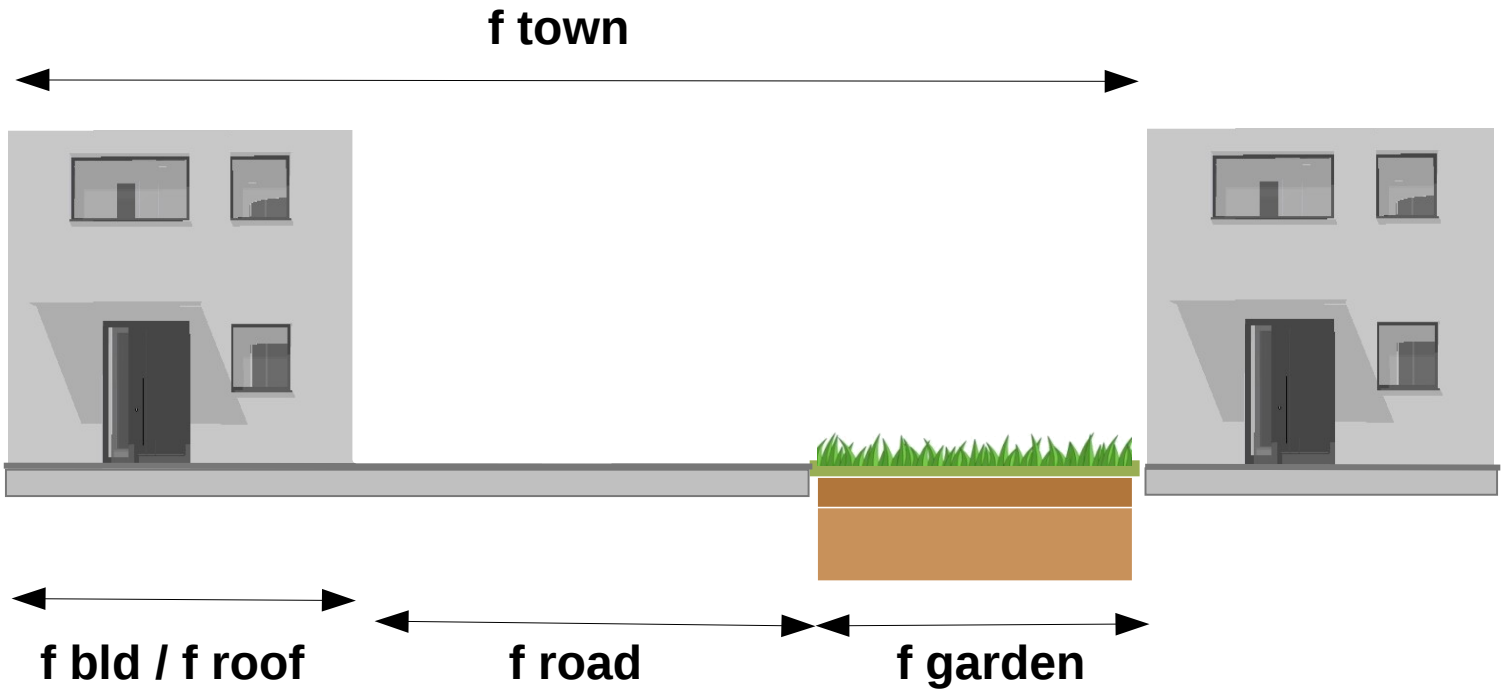


Concept of TEB (Lemonsu et al., 2012)

Main assumptions :

Occupation fraction of ground / type of surface

No spatialization

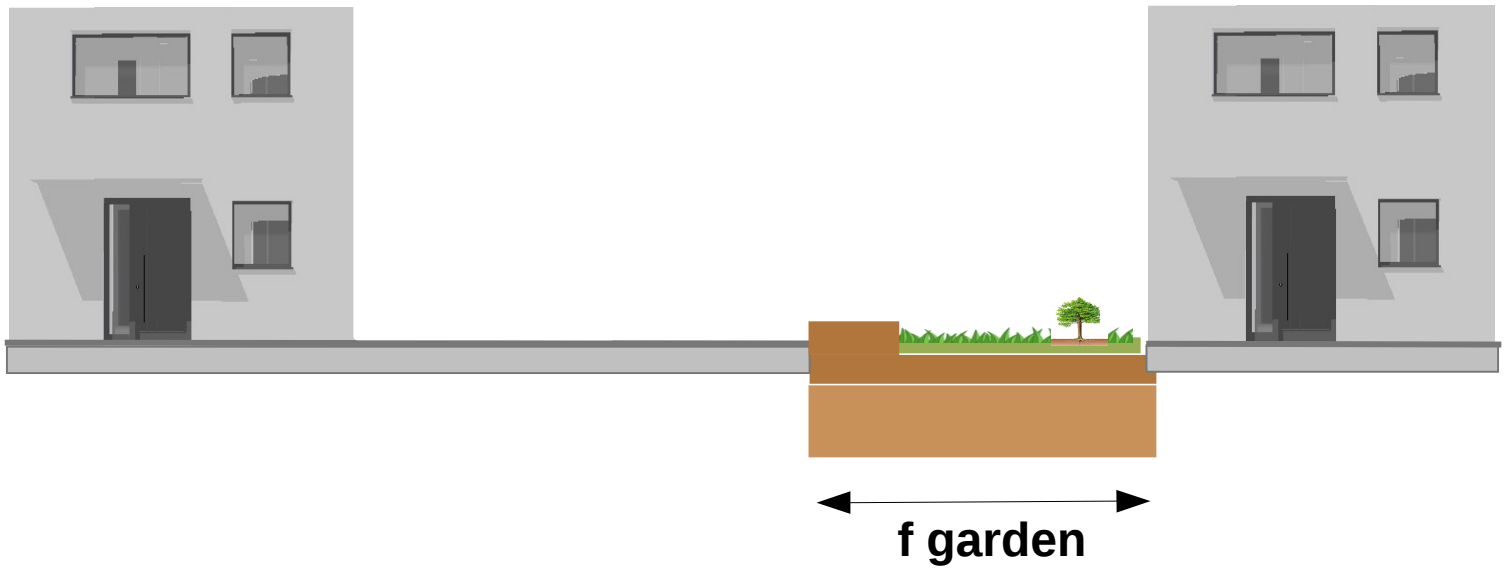


Concept of TEB (Lemonsu et al., 2012)

Before new implementations concerning urban trees :

'Garden' fraction includes 3 sub-fractions :

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

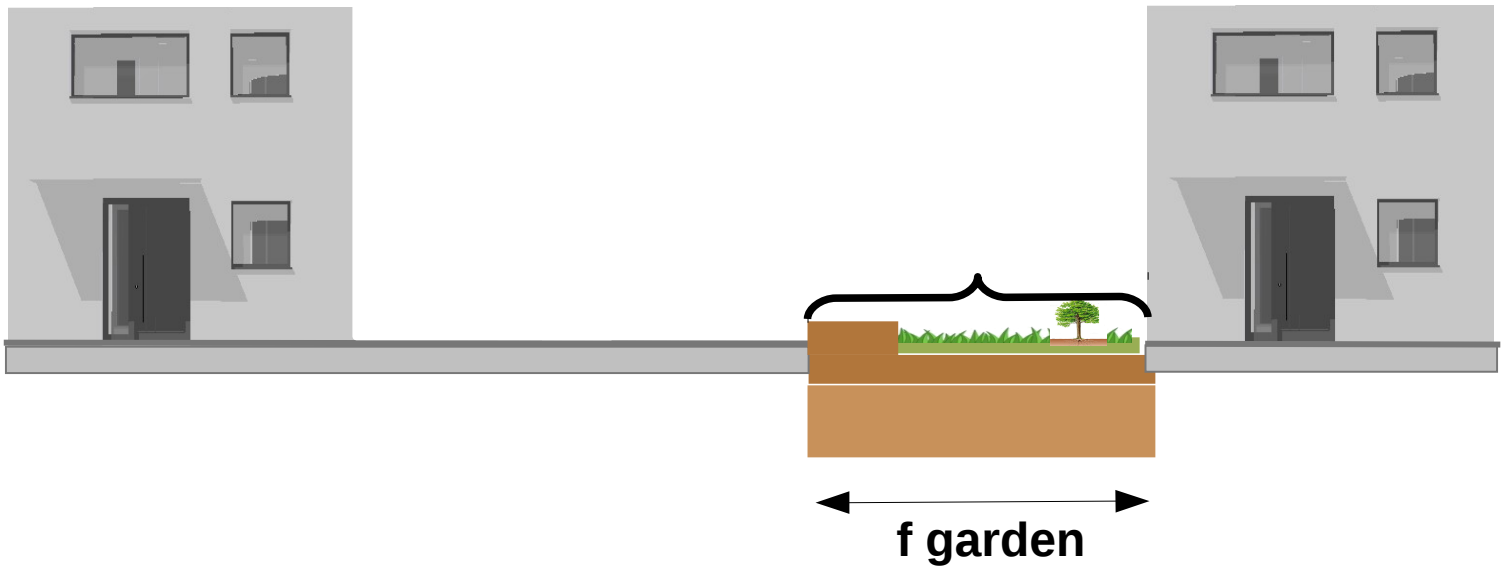


Concept of TEB (Lemonsu et al., 2012)

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

Physiological parameters averaged for garden fraction

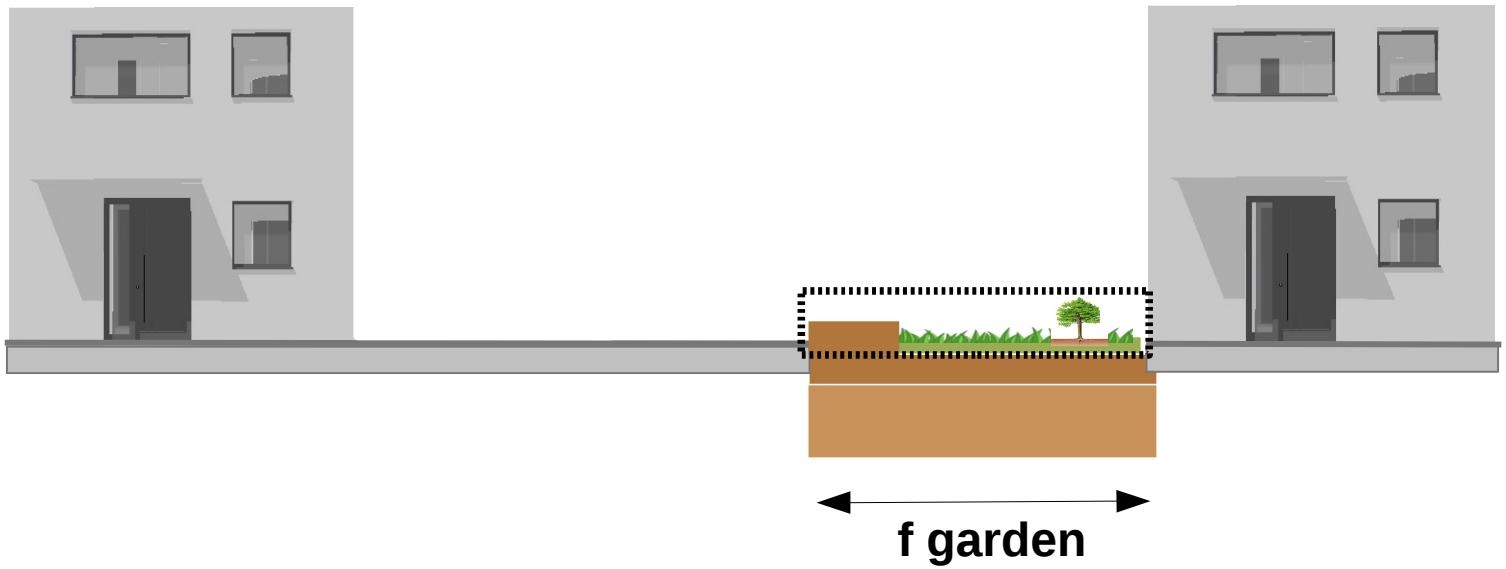
(ex : stomatal conductance, ...)



Concept of TEB (Lemonsu et al., 2012)

Before new implementations concerning urban trees :

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

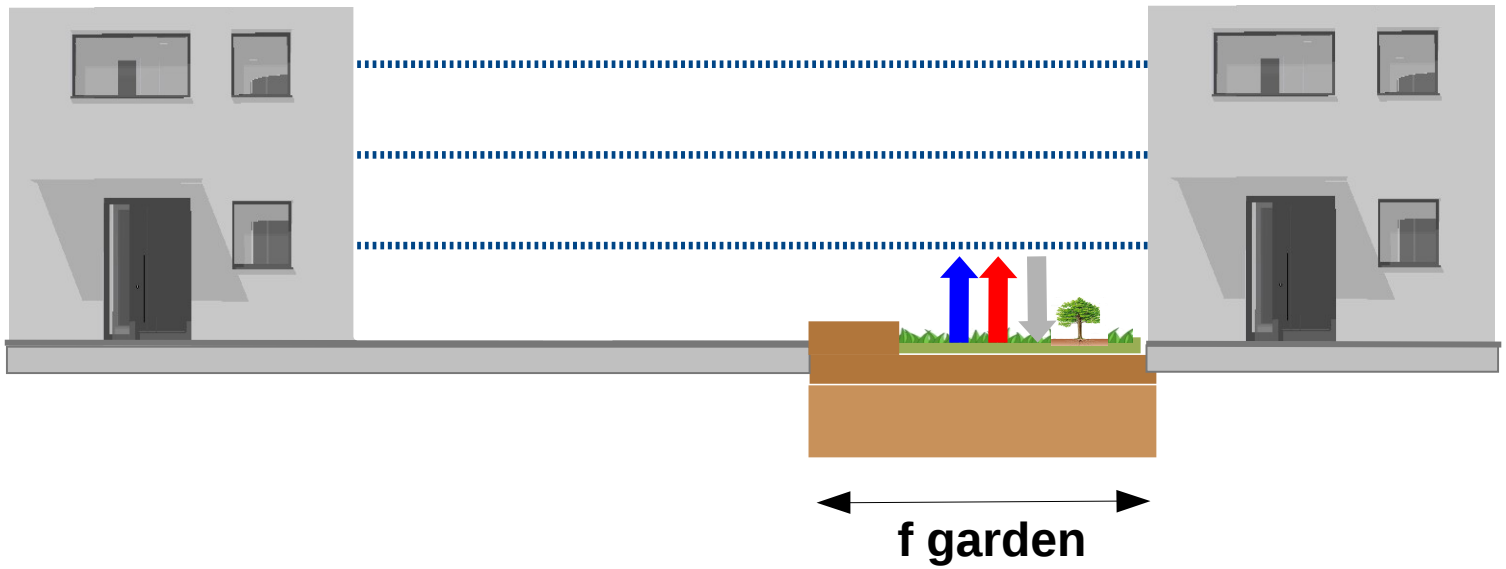


Concept of TEB (Lemonsu et al., 2012)

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

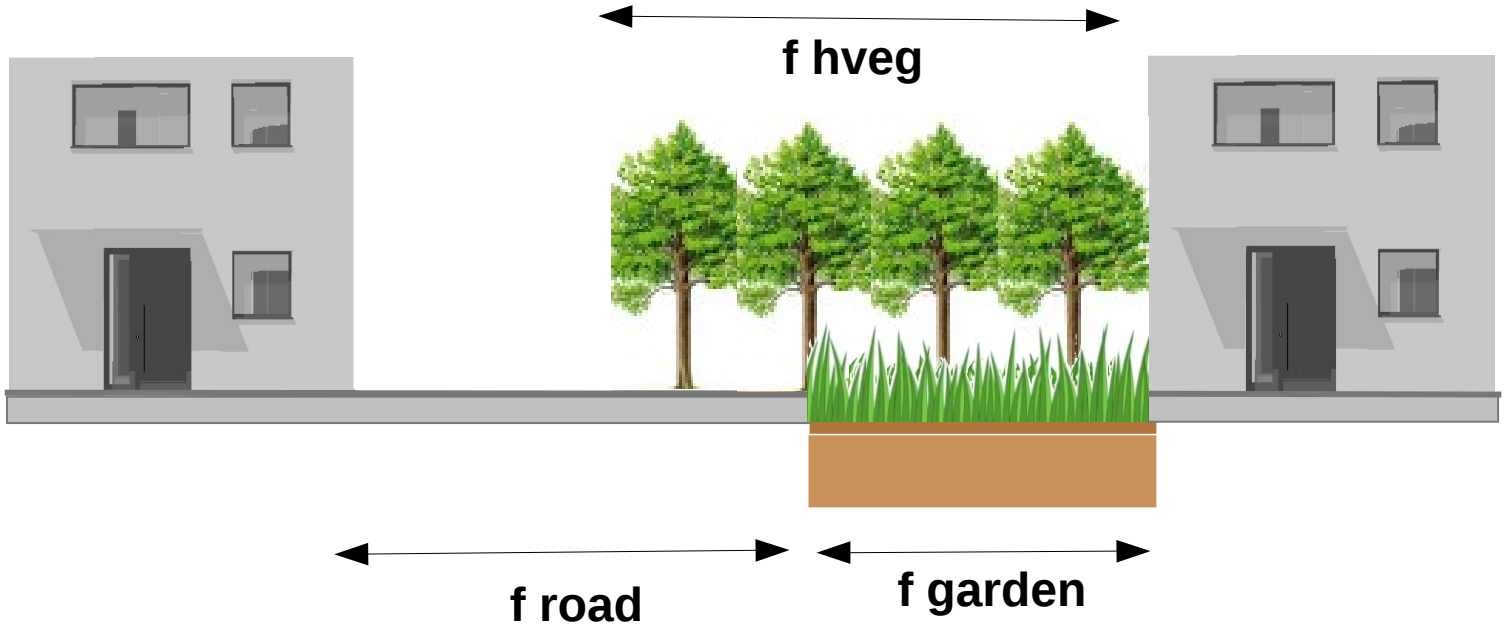
Sensible and latent heat fluxes aggregated for garden fraction (at ground)

=> limited influence in lowest part of the canyon



New definitions / parameters required for urban trees representation in TEB

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

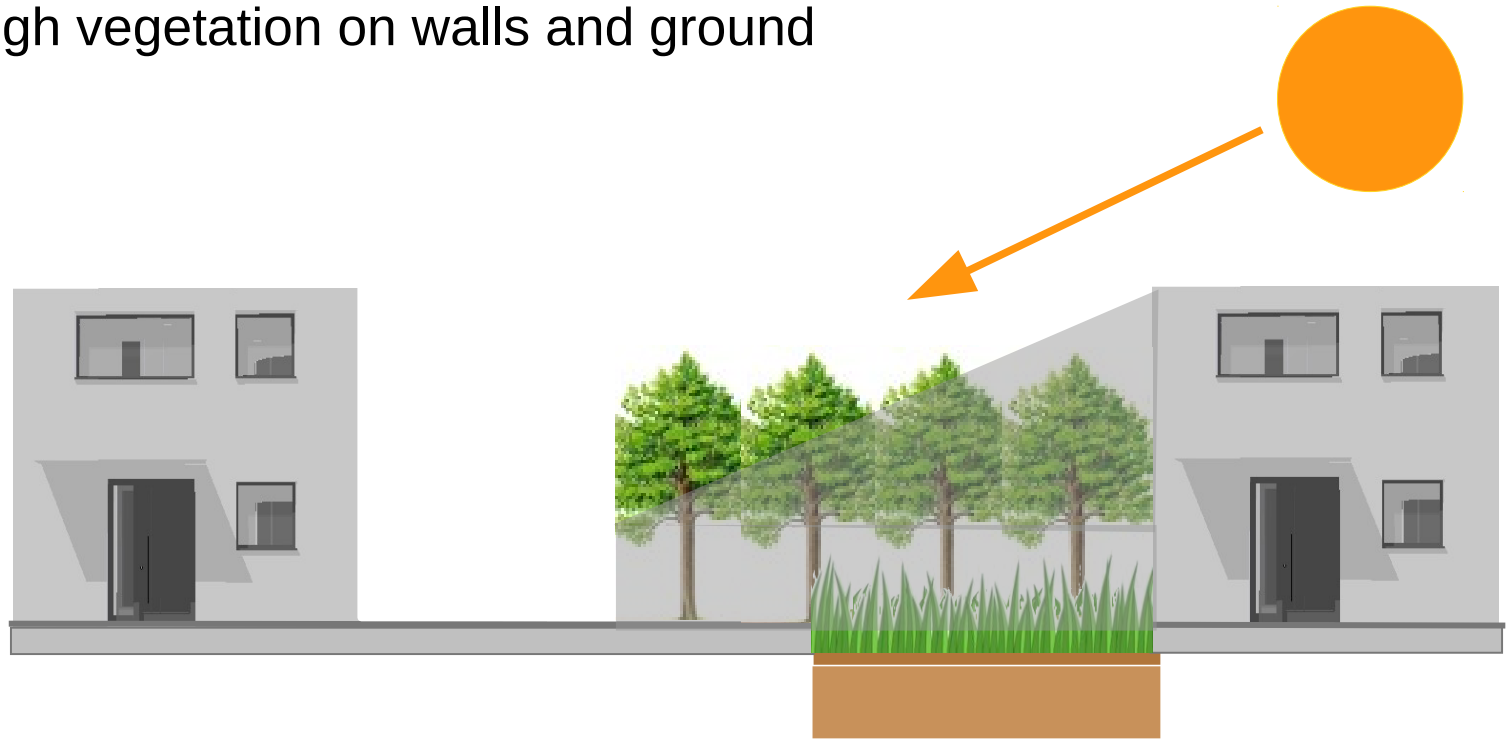


New definitions / parameters required for urban trees representation in TEB

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

Shading effects :

- buildings on high vegetation
- high vegetation on walls and ground



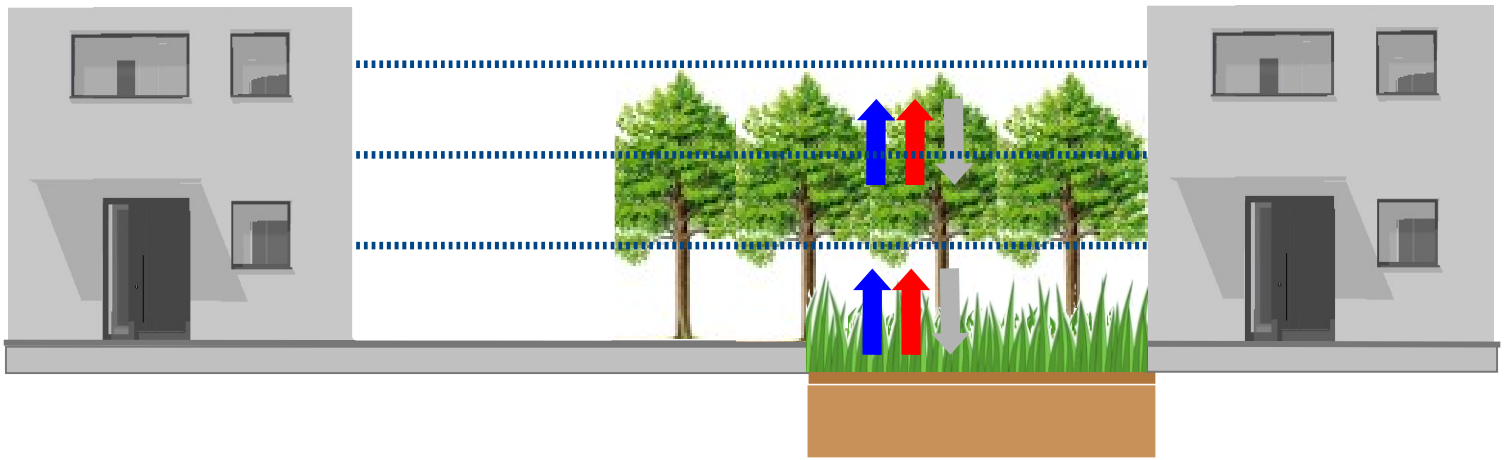
New definitions / parameters required for urban trees representation in TEB

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



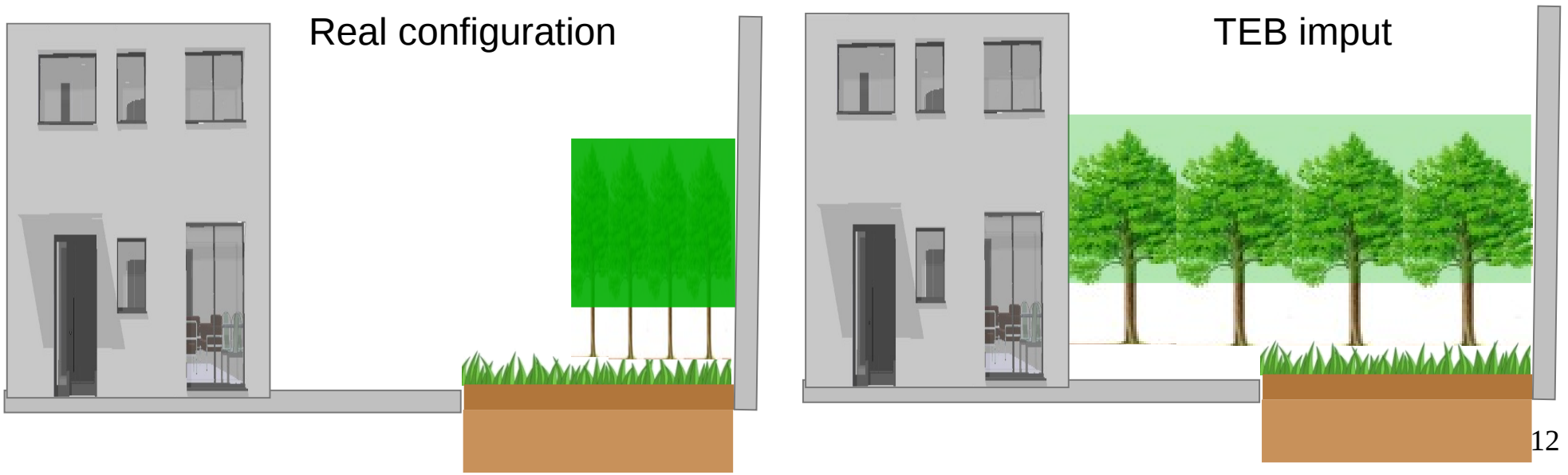
How high vegetation fraction is computed ?

High vegetation fraction is depending on :

- 2D extension (sum of crown widths)

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

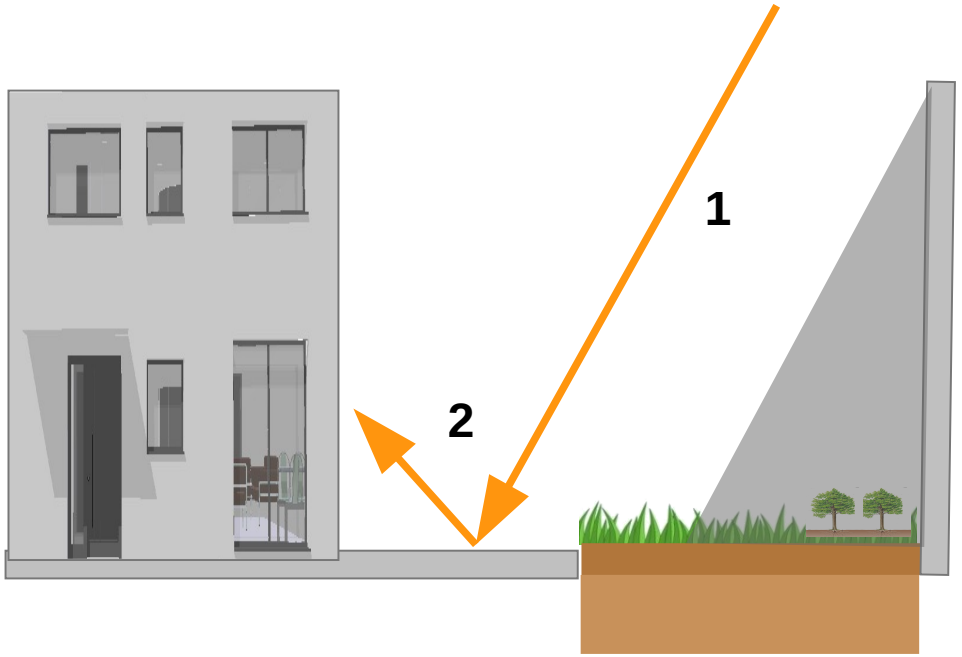
This value is homogeneously applied on canyon width (without spatialization)



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 Part of direct solar radiation reflected by each surface
=> geometric approach based on Form Factors method

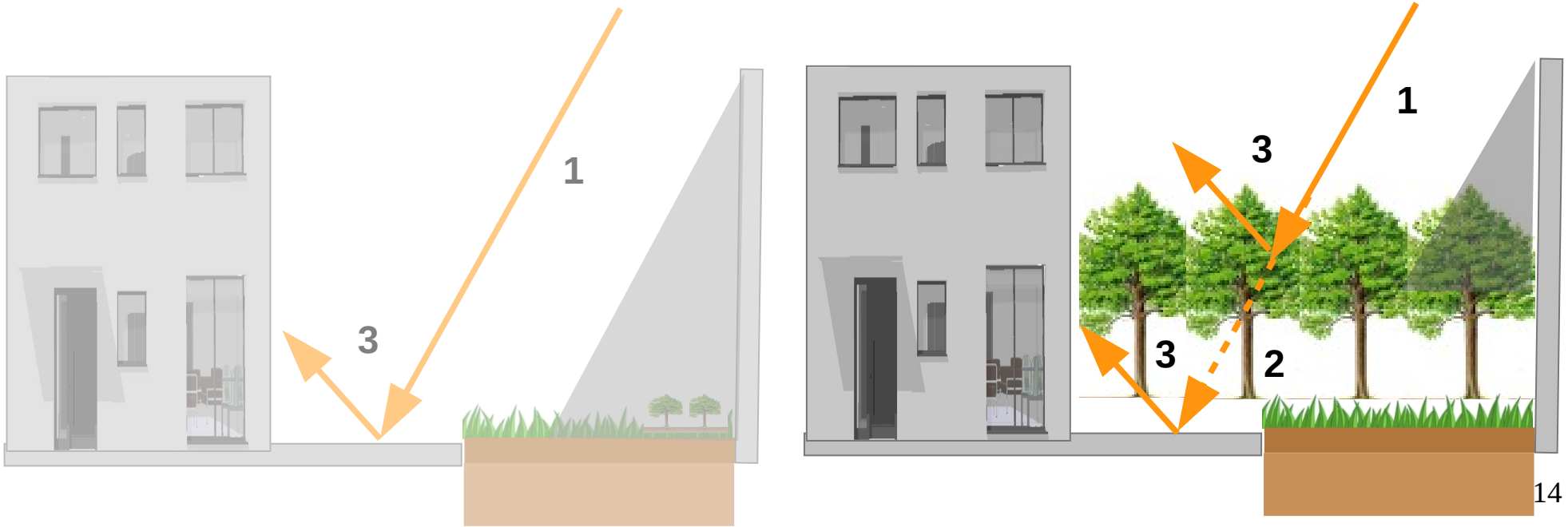


Resolving radiative balance by urban surface in TEB : identifying involved processes

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

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

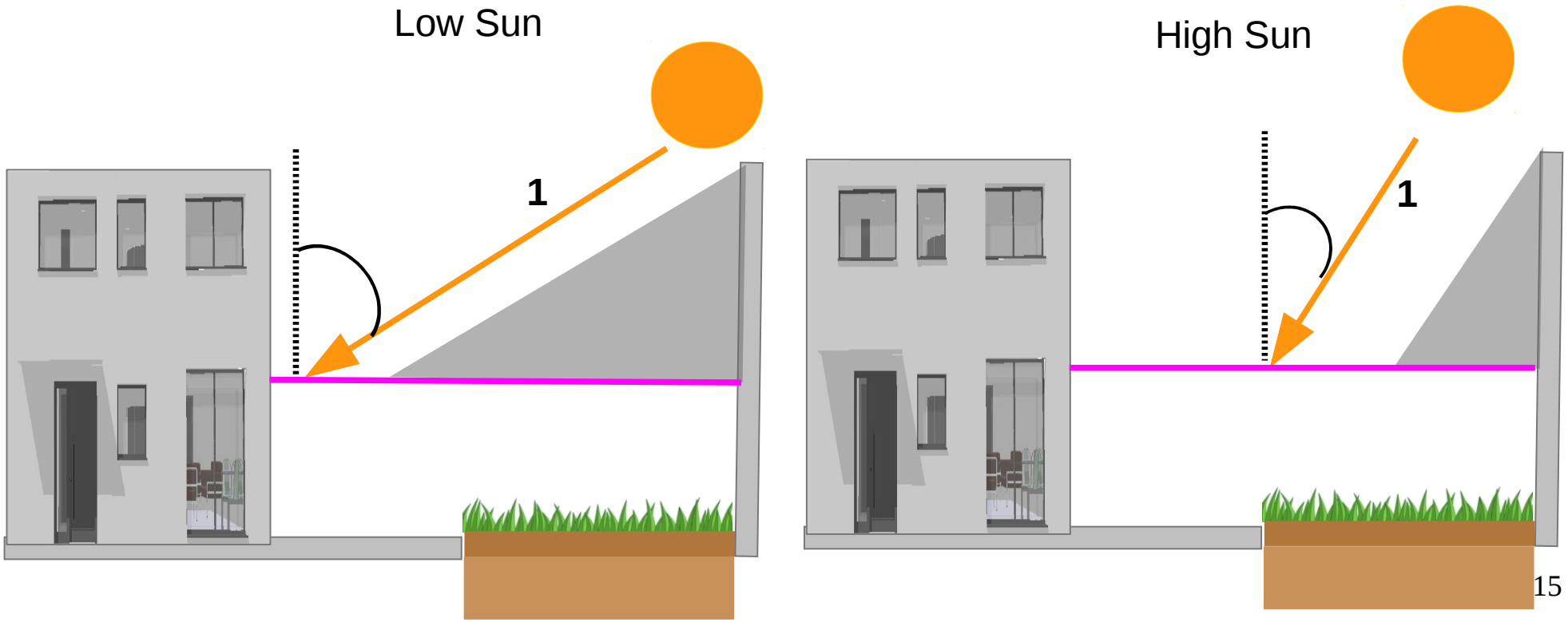
3 Part of direct solar radiation reflected by each surface
=> geometric approach based on Form Factors method



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 half-height of 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 type attenuation

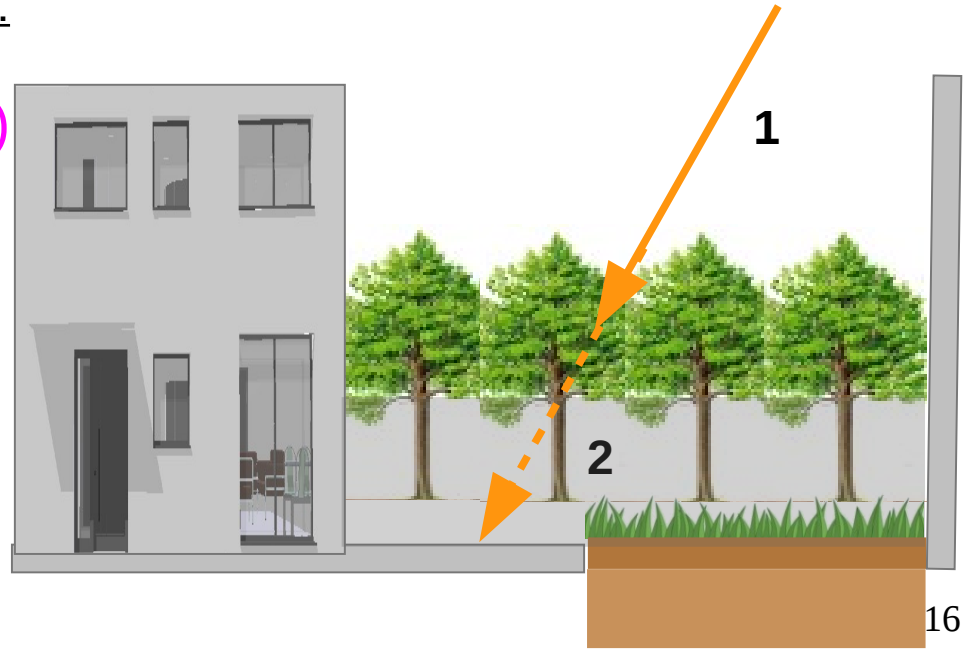
Shading of high vegetation on walls and ground

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

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

Extinction coefficient k (= 0,5 in TEB)
Homogeneous foliage distribution

Leaf Area Density ($m^3 . m^{-2}$)
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 reflected by WALL1
- transmitted through HIGH VEGETATION
- received by WALL2

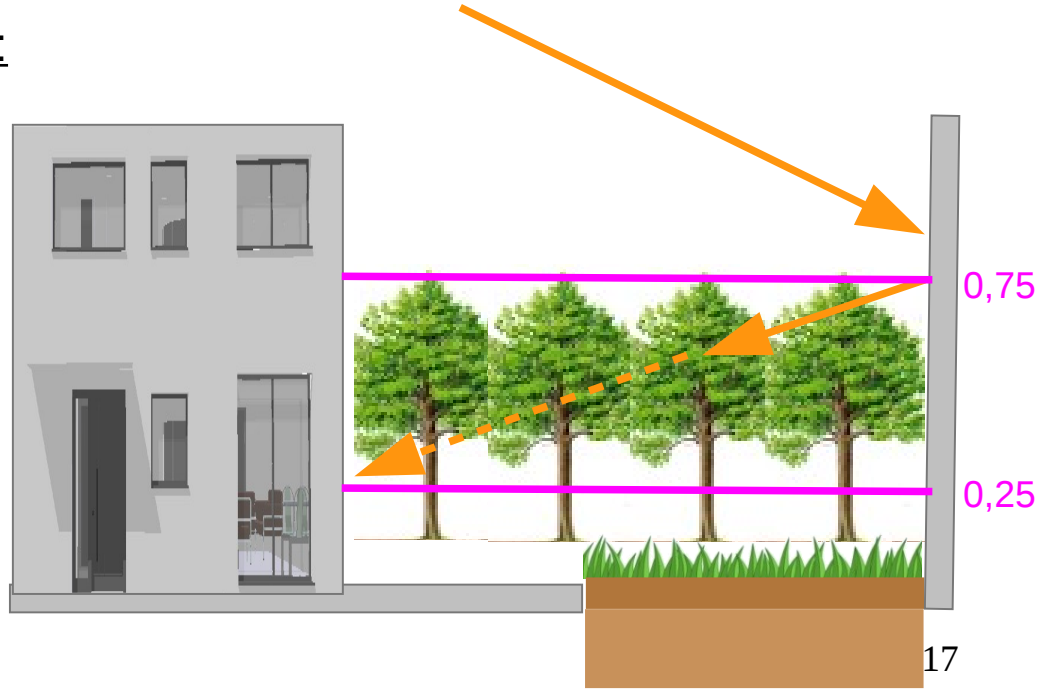
Adequate HV transmissivity, function of involved surfaces

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

$\tau_{WALL\ 1\ /\ WALL\ 2} = \exp(-k \times LAD)$

Extinction coefficient k (= 0,5 in TEB)

Leaf Area Density ($m^3 . m^{-2}$)
from wall to wall :
foliage density crossed by rays
included in 0,25 – 0,75 building height zone



Evaluation of TEB with trees : radiative budget

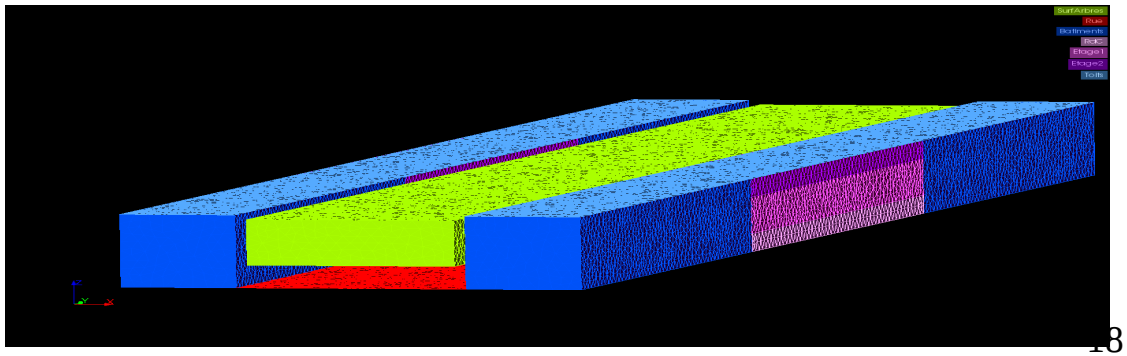
Objectives :
How to appreciate quality of radiation absorption simulation in TEB ?
How to identify configurations for which TEB assumptions can be applied or not ?

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

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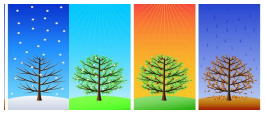
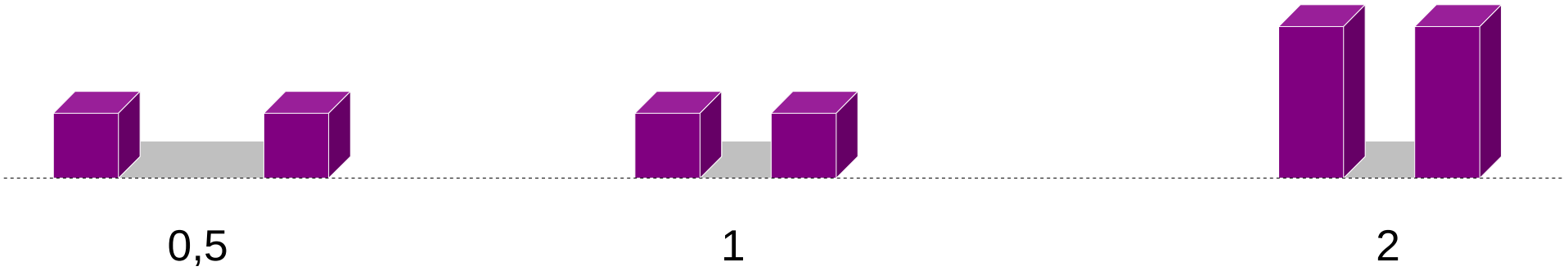
4 seasons : winter – spring – summer- autumn 

3 aspect ratios h/w :



Evaluation of TEB with trees : radiative budget

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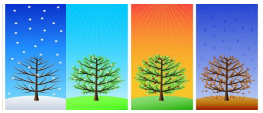
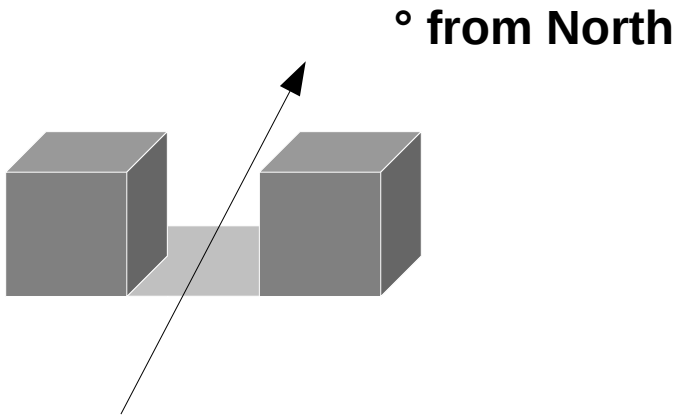


3 aspect ratios h/w : 0,5 - 1 – 2

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



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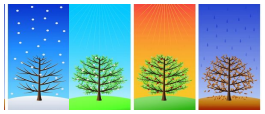
4 seasons : winter – spring – summer- autumn 

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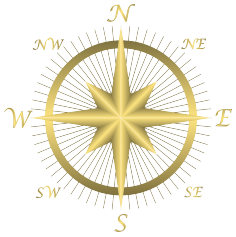
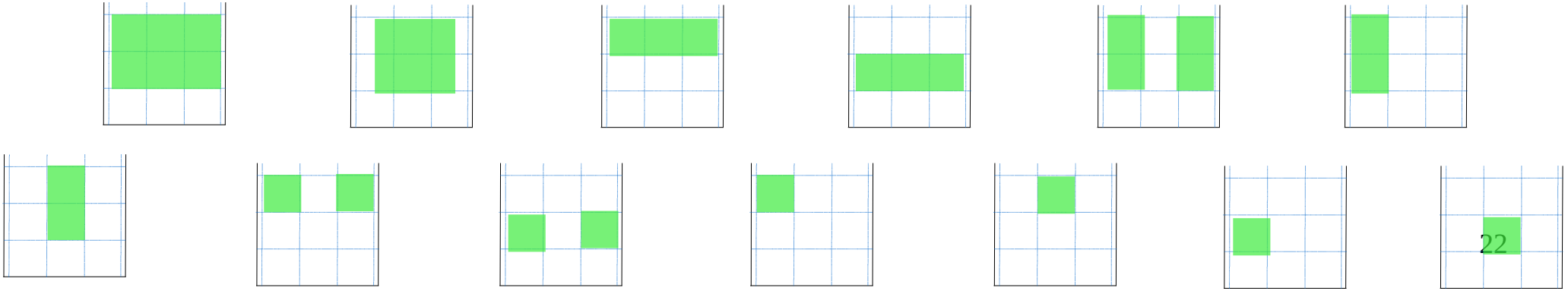
4 canyon orientations : 0° - 45° - 90° - 135° 

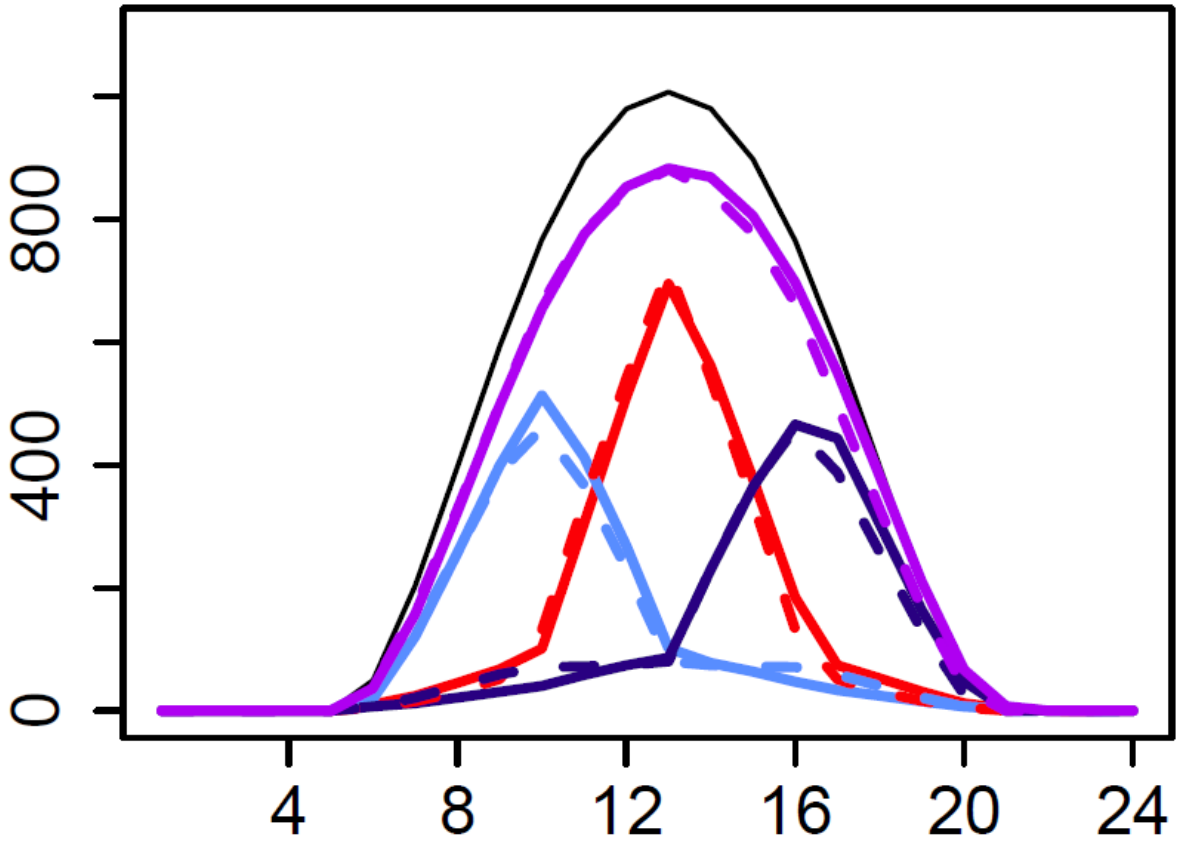
13 extreme vegetation layouts :



Evaluation of TEB with trees : radiative budget

Canyon without vegetation (control case)

Total (= direct + diffuse) solar radiation flux absorbed by each surface (W . m^{-2})
h/w = 1 - orientation 0° - summer day



SOLENE
TEB

Road
WallA
WallB
Sum
Incident

Greater errors for walls

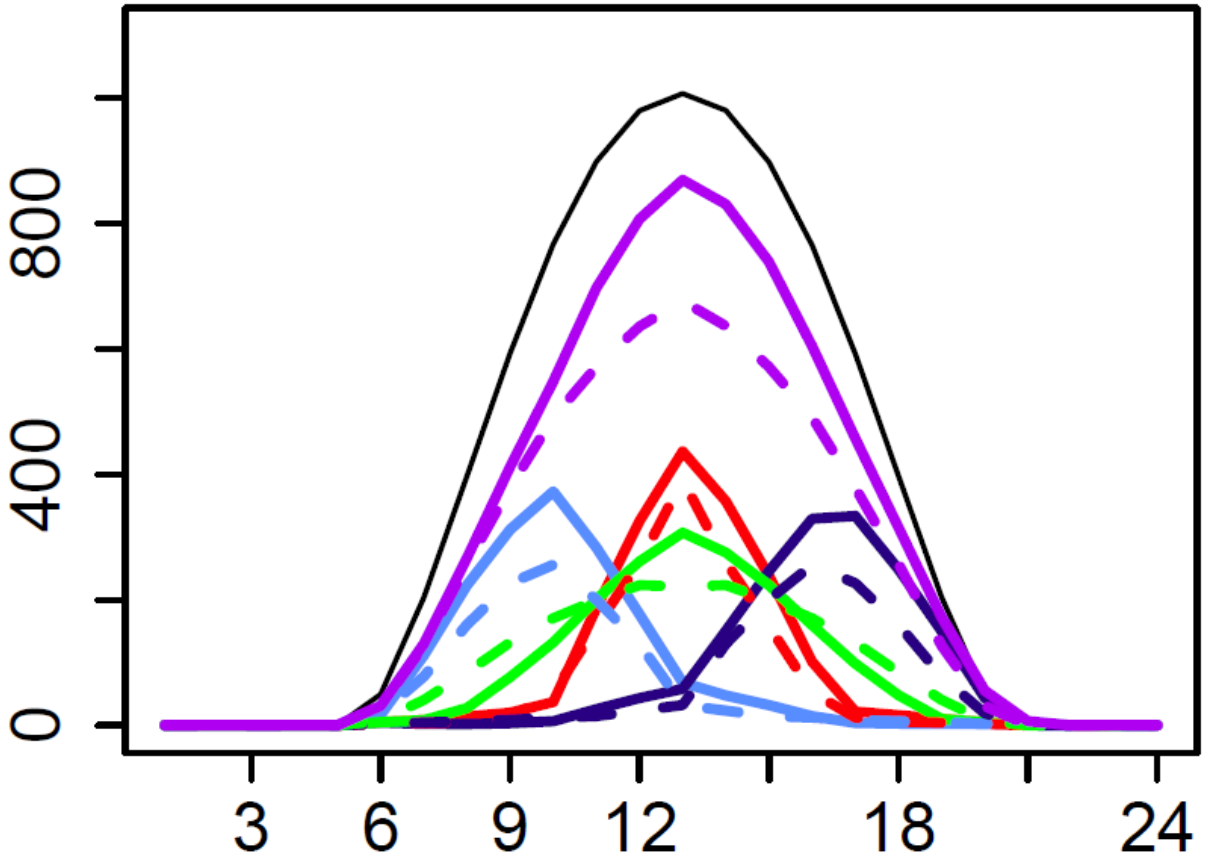
Evaluation of TEB with trees : radiative budget

Extremely vegetated canyon

SOLENE
TEB

Road WallB Trees
WallA Sum Incident

Total (= direct + diffuse) solar radiation flux absorbed by each surface (W . m^{-2})
h/w = 1 - orientation 0° - summer day



systematic overestimate of absorption in TEB

except for high vegetation here (geometrical effects)

Conclusions :

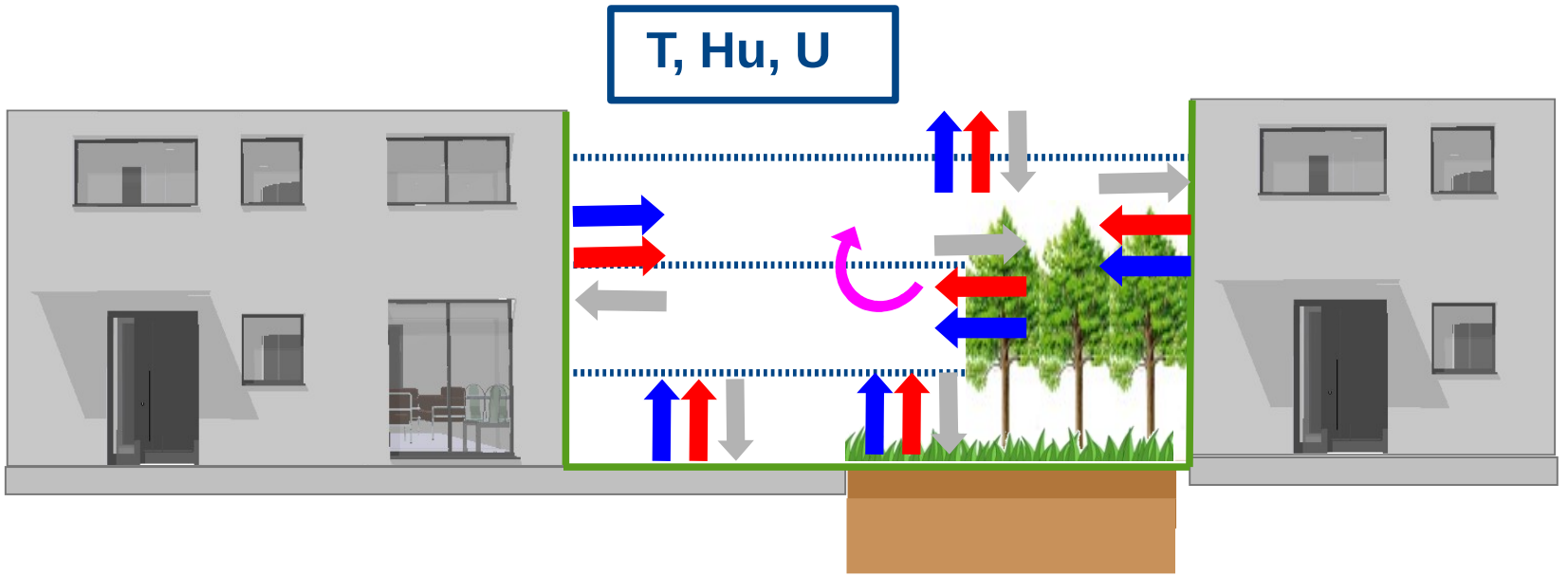
Validation of solar part of radiative budget (canyon forms, orientations, seasons)

Need improvements of absorption simulation in vegetated canyons

IR exchanges already computed (same form factors and transmissivity terms)

Perspectives :

Energy budget by high vegetation (realistic vertical gradient + aerodynamic effect)



WELCOME TO TOULOUSE !

THANK YOU FOR YOUR ATTENTION

Sources of images
http://encyclopedie_universelle.fracademic.com/1182/ARBRE
http://niwaki.unblog.fr/2013/03/15/parc-toulouse/