A sensitivity Analysis of Urban Boundary Layer On Canopy Description

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My purpose :

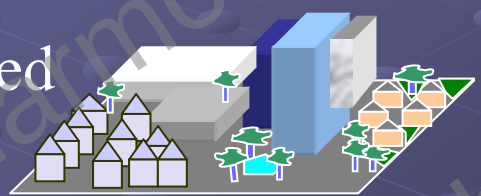
To Perform Urban Boundary Layer Flow Simulations at meso scale :

- Use of the Urban Soil Model SM2-U for the bottom boundary condition
- Use of an urban classification with geographical database

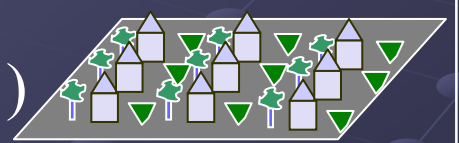
➢ parameterization of the urban canopy : which degree of detail has to be chosen ?

- simulations already carried out at moderate wind forcing (3 m/s) :

4 districts detailed city: ($S1_{ref}$)



Homogeneous mean city : ($S2_{ref}$)



- UBL flow depends on the city representation

➢ Detailed city better reproduces urban meteorological phenomenon (UHI…)

➢ What about the results at weak wind ? For a coastal city ?

Outline of this Session :

- The atmospheric model SUBMESO
- The soil model SM2-U
- Simulations setup
- Energy budget analysis on 2 districts
- Dynamic flow analysis
- A coastal city case analysis
- Conclusions & Future research

The Atmospheric model

- Derived from ARPS
- Navier stokes equations

- Non compressible
- Non-hydrostatic

SUBMESO

- LES simulation

  (Large Eddy Simulation)
- 1.5 order TKE equation

  (to model sub-grid fluxes)

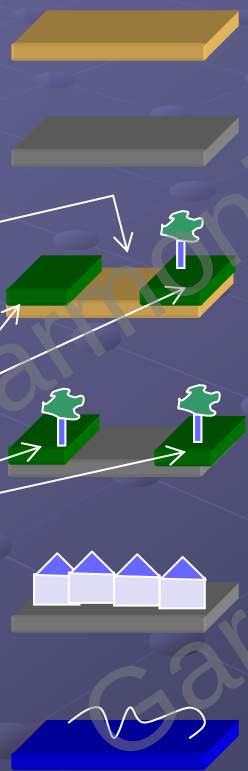
- Mesh resolution range : 10 m - 10 km
- « terrain following » coodinates : grid vertically streched

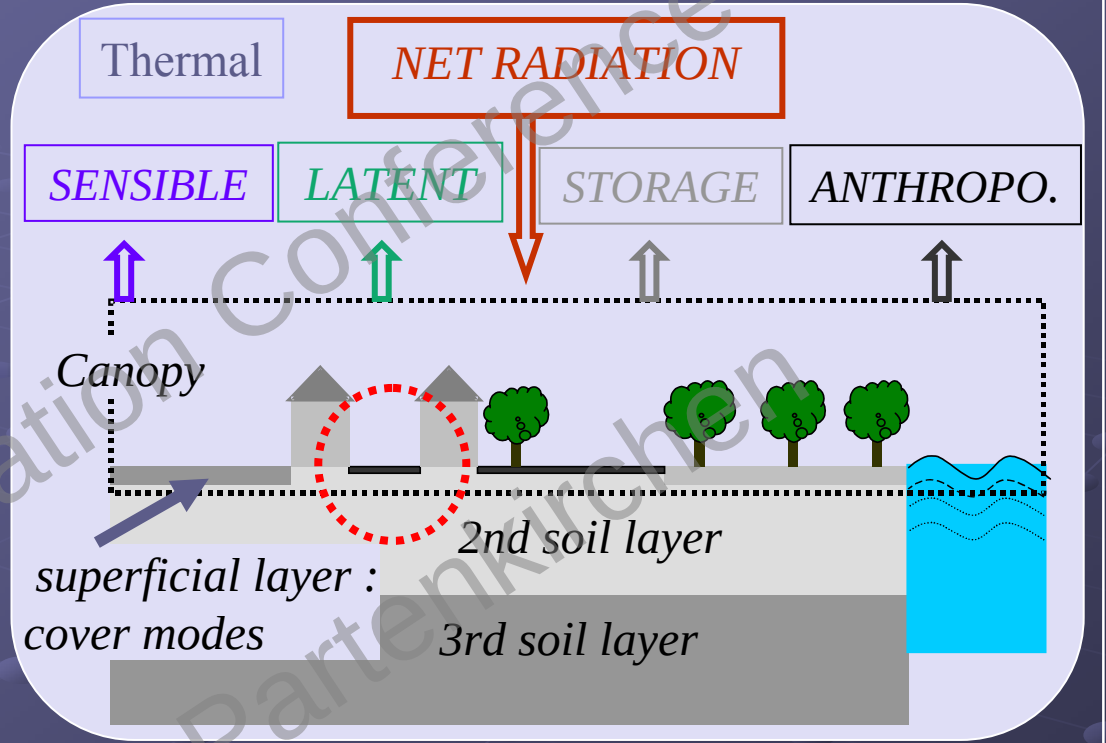
Mesh size in this session :

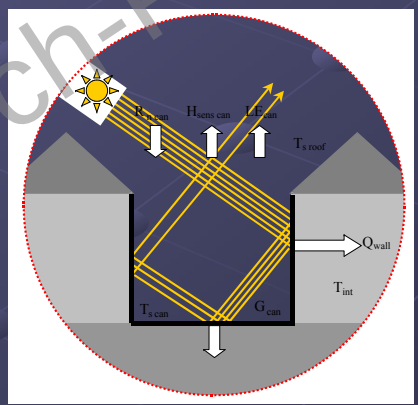
- horizontal = 1km x 1km
- vertical : 41 levels (z_{min} : 40 m ; Rayleigh layer top : 4600 m)

The soil model : SM2-U

- A force-restore model (based on ISBA)
- thermal & water budgets
- 7 types of cover :
  1. Bare
  2. pav
  3. nat
  4. Vegn
  5. Vega
  6. roof
  7. wat







- Street canyon : effective albedo calculated
  - ➔ radiative trapping

Simulations performed on an academic european city :

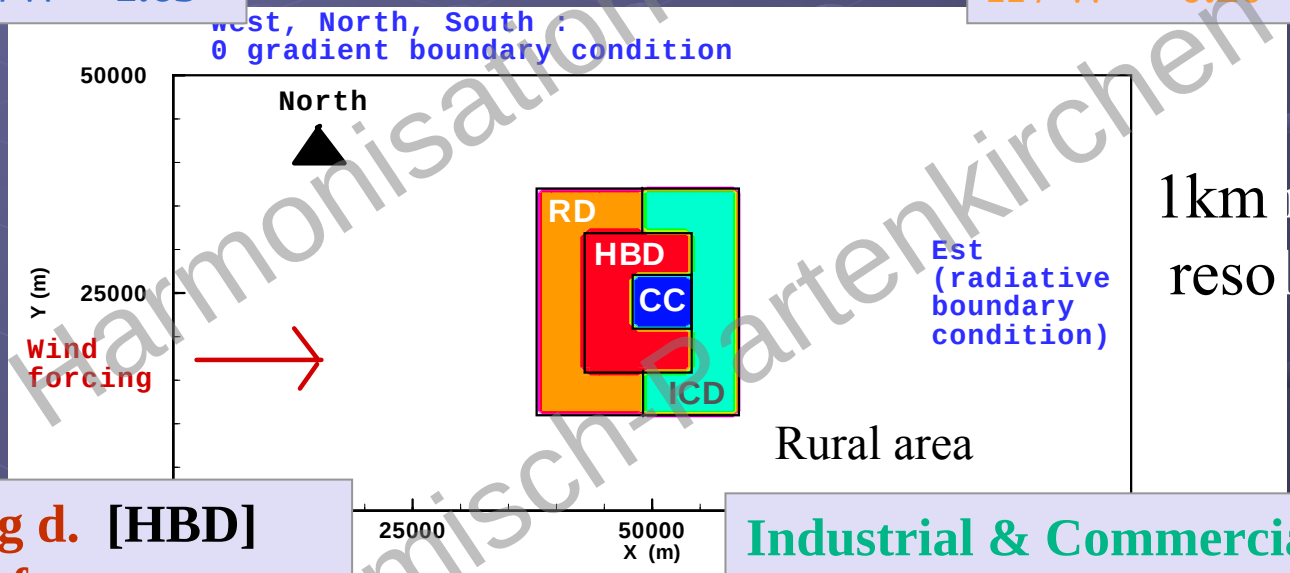
S1 : a 4 districts detailed city

City Centre [CC]
59.5 % buildings
13% vegetation « vegn »
$Z0_m$ = 1.90
Aspect ratio H/W = 1.63

Wind forcing :
Simulation $S1_{ref}$: 3 m/s
$S1_{lw}$: 1 m/s

Residential d. [RD]
50 % vegetation « vegn »
22% paved surfaces
$Z0_m$= 0.54
H / W = 0.20

$\Delta t = 1s$
30 june



1km mesh resolution

High Building d. [HBD]
52% paved surfaces
16% vegetation « vega »
$Z0_m$ = 1.27
H/W = 3.0

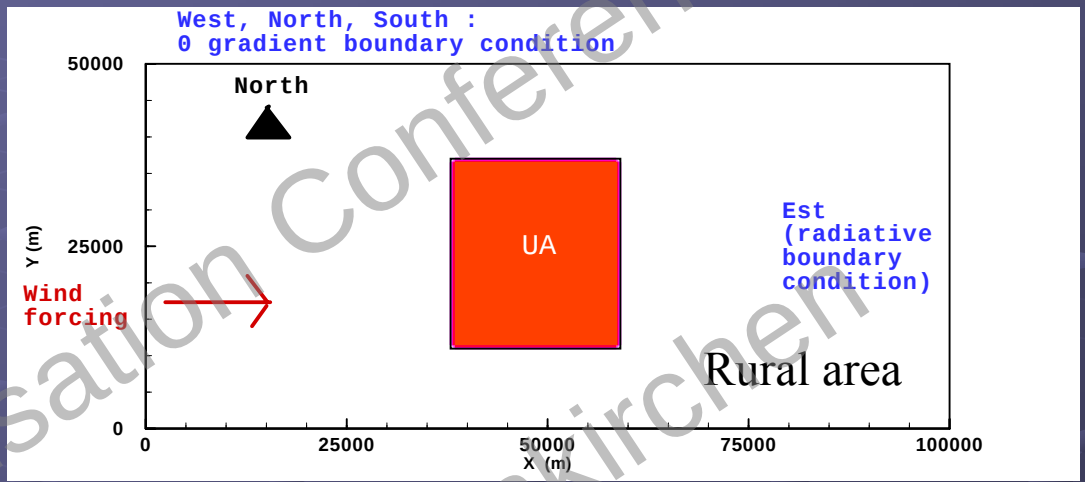
Industrial & Commercial d. [ICD]
58 % of paved surface
1% vegetation
Z0m = 0.64
H / W = 0.40

Simulations performed on an academic european city :

S2 : A mean city (averaged characteristics)

Wind forcing :
Simulation $S2_{ref}$: 3 m/s
$S2_{lw}$: 1 m/s

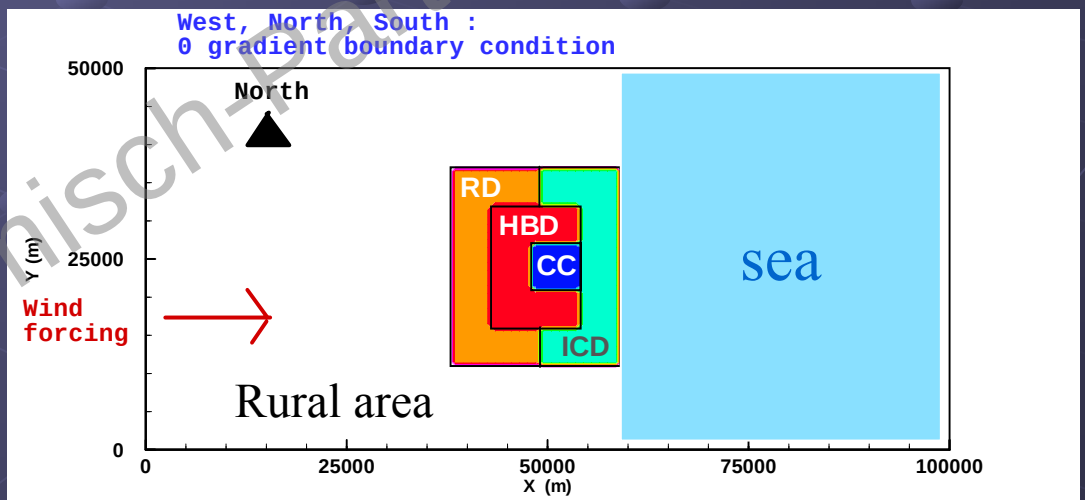
Urban Area [UA]
31 % buildings
$Z0_m$ = 0.77
H/W = 0.5



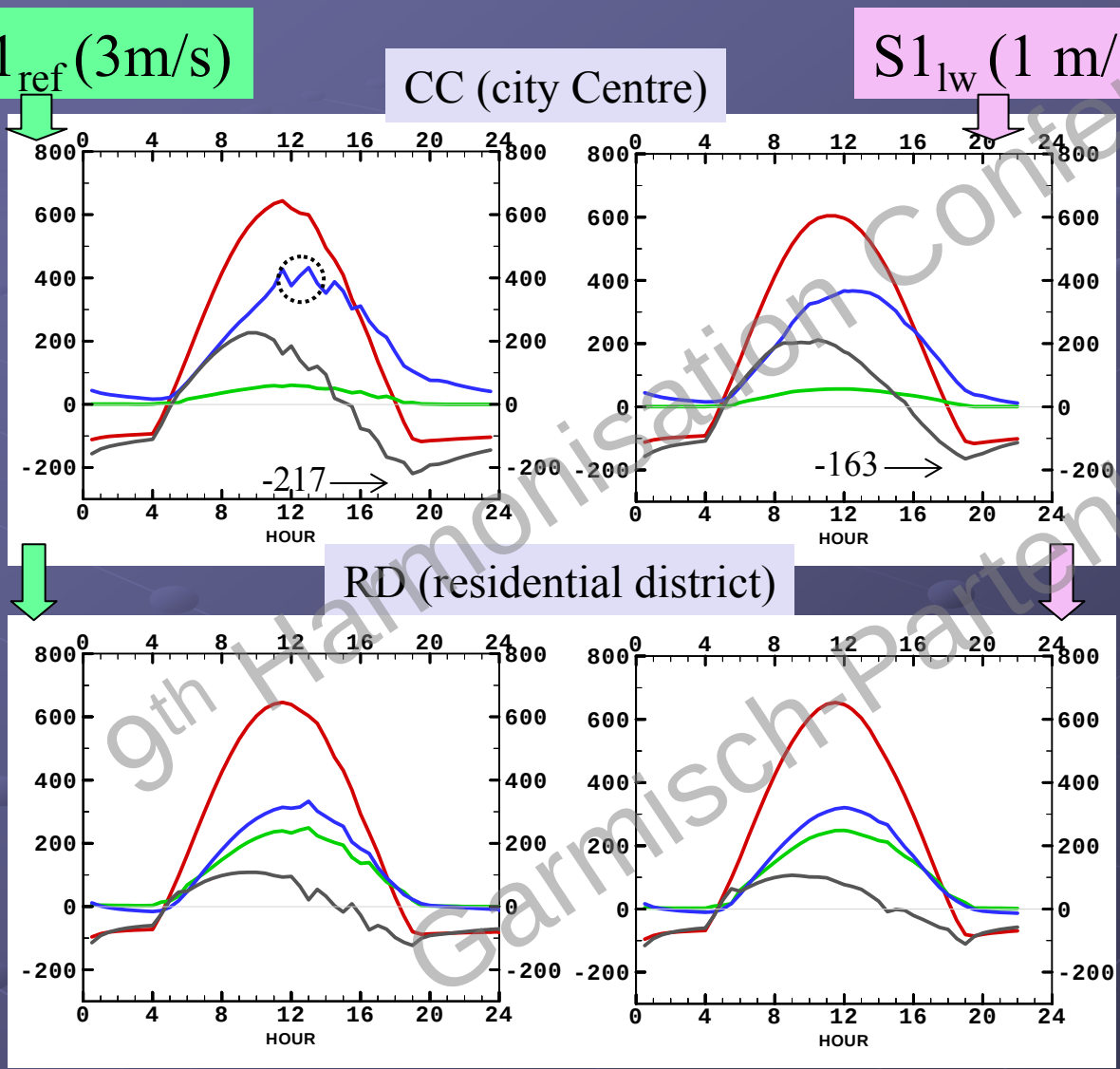
S3 : A coastal city (detailed city + sea)

Wind forcing :
Simulation $S3_{ref}$: 3 m/s
$S3_{lw}$: 1 m/s

SEA
Ts = 18°C

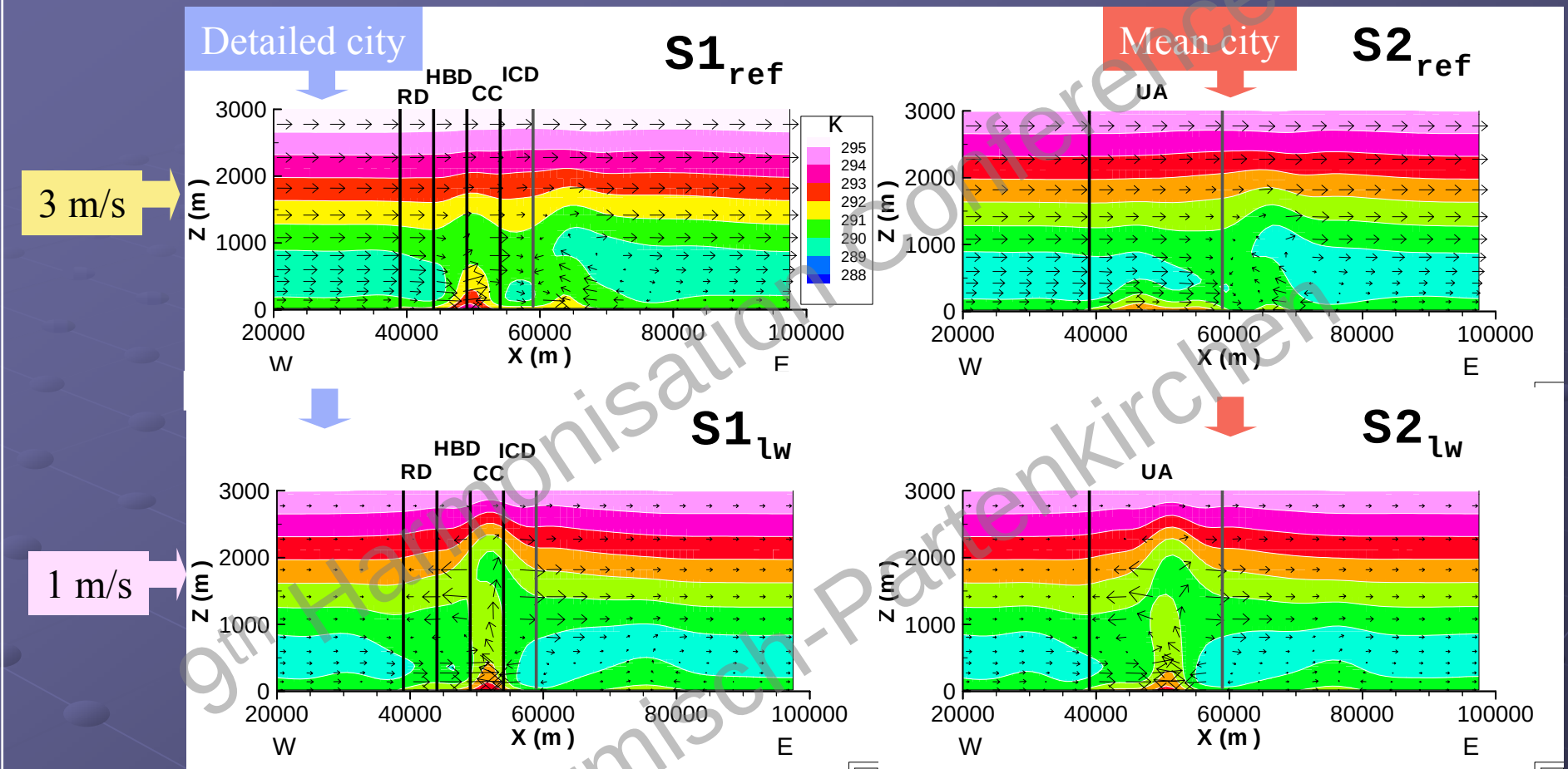


Energy budgets on 2 districts for the detailed city : S1



- Wind velocity effect on the sensible & storage heat fluxes :
  - ⇨ CC : less energy stored at low wind forcing
  - ⇨ disturbances at 3m/s (wind advection)

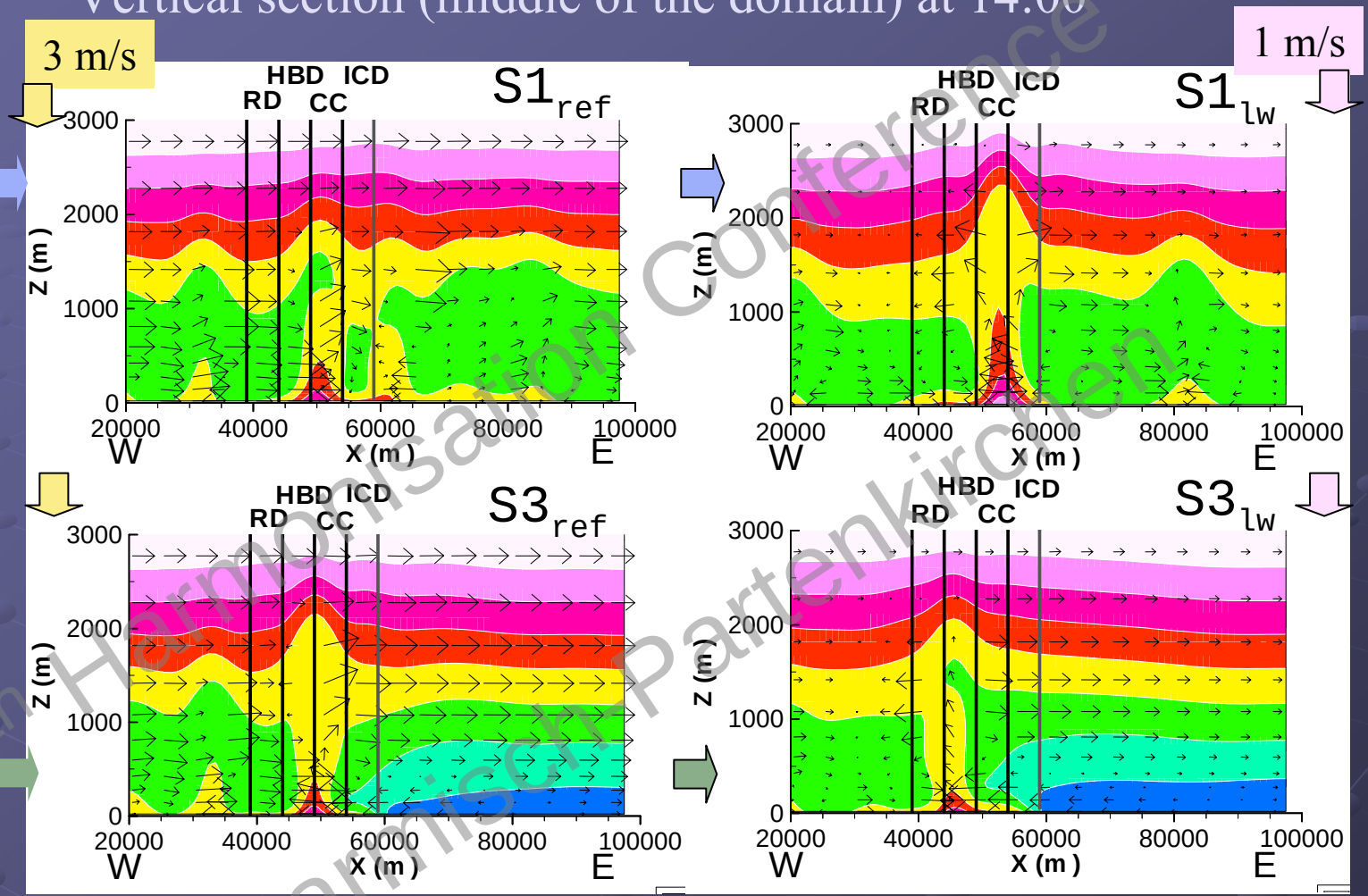
Urban boundary layer analysis :
vertical section (middle of the city) at 12:00 UTC



- Convective cells generated over the city : + intense in low wind cases (lw)
- At moderate wind : air mixed rural/city due to horizontal advection
- Symmetry for the mean city & for the detailed city with a weak wind forcing

A coastal city case : modification of the city breeze :

Vertical section (middle of the domain) at 14:00



- $S3_{ref}$: ↗ up-lifting over the city : confrontation between city & sea breezes
- $S3_{lw}$: ↗ of city breeze inland penetration & ↘ city influence

Conclusions

- SM2-U coupled with SUBMESO : urban canopy structure is taken into account
- At moderate wind, simulations showed the UBL flow dependance on canopy description
- For a weak wind forcing,
  - Districts specificities are kept
  - About the same UBL flow behavior with a detailed & a mean city
- In case of a coastal city :
  - city influence on the flow is reduced at low wind forcing
  - a mean city may over-estimate the inland sea breeze penetration ...

⇨ In this case, urban heterogeneities have to be taken into account in a case of weak wind forcing

Future research

- Simulations over real coastal cities :
  - Marseille (UBL/ESCOMPTE experiment, summer 2001 : complex topography, passive tracer dispersion…)
  - Copenhagen (inter-comparisons of models DMI-HIRLAM/SUBMESO/MM5)

Thanks for your attention ...

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