Coupling time domain acoustical and mesoscale meteorological models

GDR Visible – Bron

P. Aumond, *B. Gauvreau, C. Lac, V. Masson, M. Berengier*

17th may 2011

Introduction

Influence of meteorology on sound propagation…

Objective :

Using a reference model coupling a meso-scale meteorological model (MESO-NH) and a time domain acoustic model (TLM) in order to investigate this phenomena

Outline

- Introduction
- Time domain acoustic model: *Transmission Line Matrix*
  - Model presentation
  - How to take into account meteorogical effects ?
- Meteorological model
- Preliminary results
- Conclusion

Acoustic model

Choice

Characteristics required by this model:

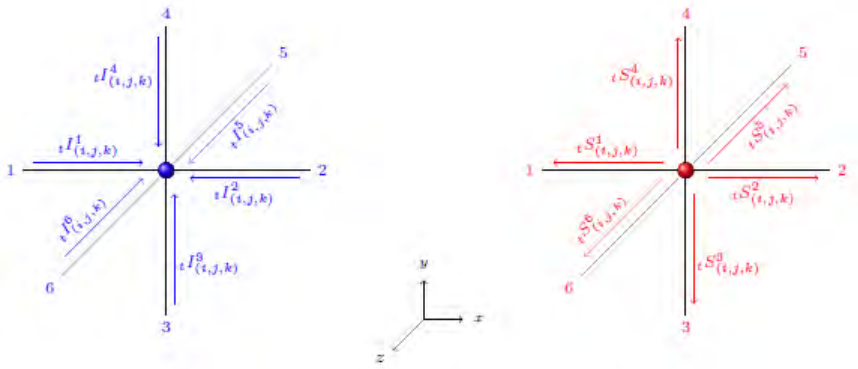
Strong accuracy !
Taking into account different geometries, materials, …
Taking into account atmospherical effects…

A choice:

Transmission Line Matrix

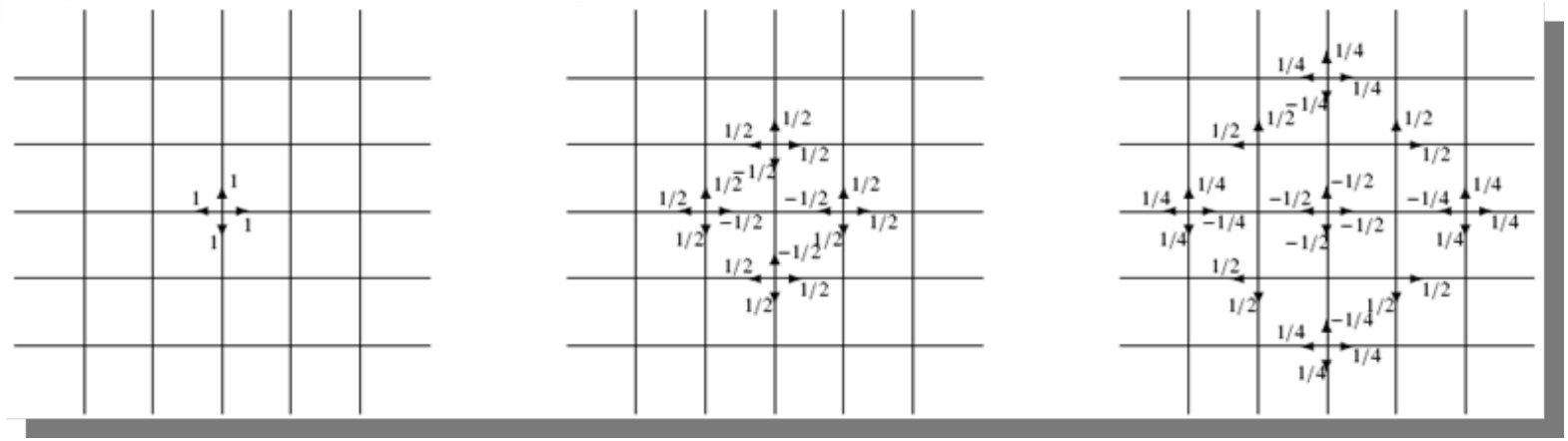
G. Guillaume, « *Implementation of complex impedance conditions and absorbing layers into a transmission line matrix model for urban acoustics applications* » *Euronoise, 2009*

Principles



Connection law between each nodes
« Diffusion node by node »

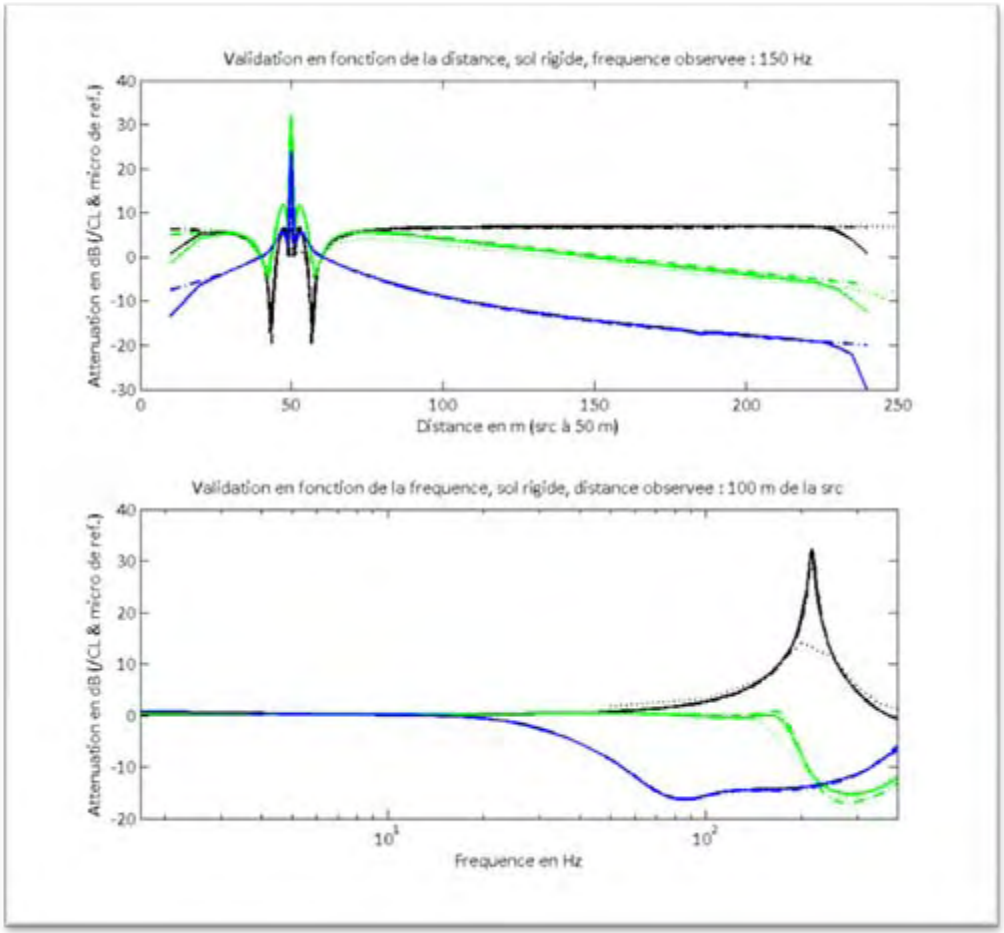
~ finite difference of the propagation equation



G. Guillaume, « *Implementation of complex impedance conditions and absorbing layers into a transmission line matrix model for urban acoustics applications* » *Euronoise, 2009*

TLM

Validation in standard case



Eq. parabolique
TLM
analytique

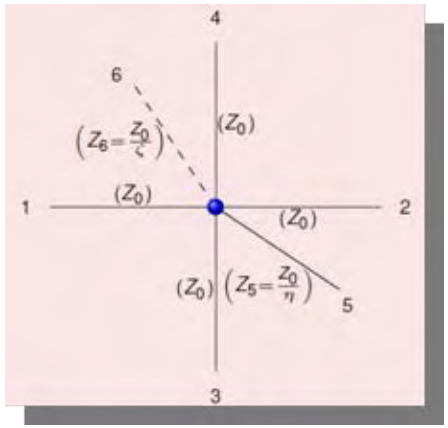
Ref.
100 cgs (miki)
10 cgs (miki)

Src. = 2 m
Rec. = 2 m

Take into account meteorology

Absorption

$$t^{\zeta}_{(i,j)} = -\alpha\sqrt{t^{\eta}_{(i,j)} + 4}\,\Delta l\,\frac{\ln(10)}{20}$$



Celerity (wind, temperature)

$$\Delta p - 1/c_{eff}(x,y,z,t)\, d^2p/dt^2 = 0$$

$$t^{\eta}_{(i,j)} = 4\left[\left(\frac{c_0}{t^{c_{eff}}_{(i,j)}}\right)^2 - 1\right]$$

c_{eff} *under wind effects depends on wave direction propagation !*

$$c_{eff} = c_0 + ||\vec{u}||.\cos\alpha$$

How to get the wave front direction ?

G. Dutilleux, « Applicability of TLM to wind turbine noise prediction » , 2nd International Meeting on Wind Turbine Noise, Lyon, 2007

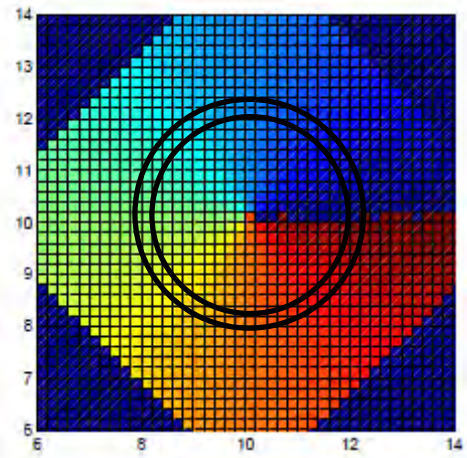
Wave propagation

Direction

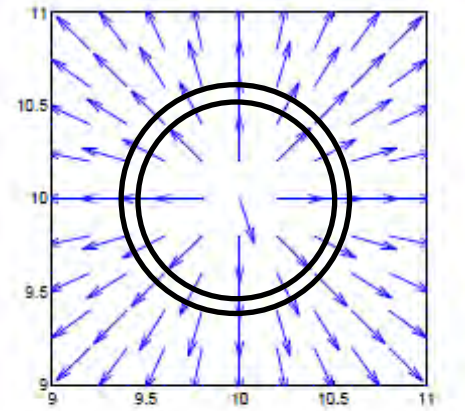
$$\langle \vec{I} \rangle_\lambda = \langle p * \vec{v} \rangle_\lambda$$

Valid for Long Range Sound Propagation :

- Far field
- Non stationnary field
- Non diffuse soundscape

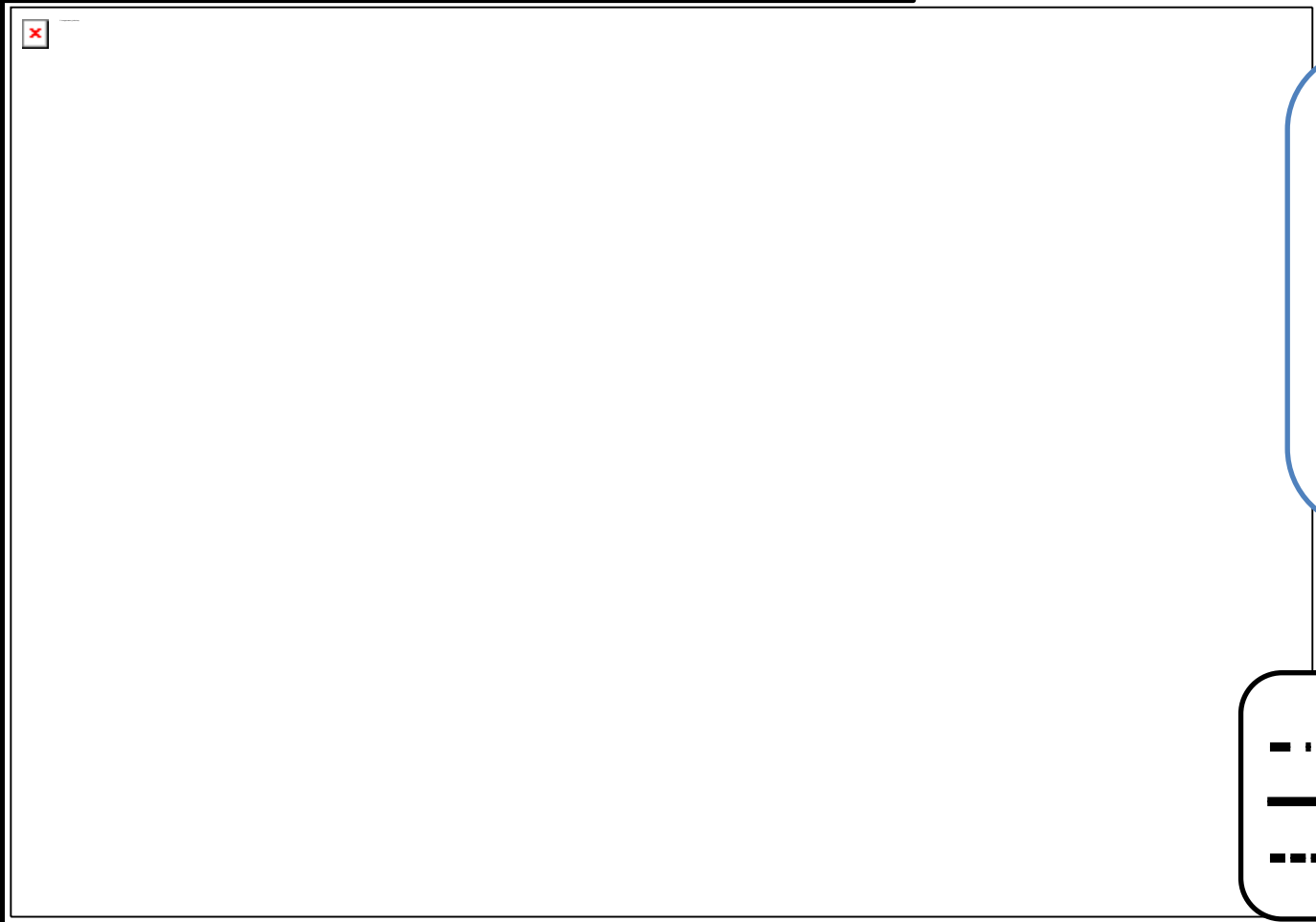


Direction of propagation



G. Dutilleux, « Applicability of TLM to wind turbine noise prediction » , 2nd International Meeting on Wind Turbine Noise, Lyon, 2007

Take into account meteorology



Wind vertical gradient
0.2 $m.s^{-1}.m^{-1}$

Domain size = 250 m*70 m
Source height = 2,025 m
Resolution tlm = 0,05 m
Sol herbeux : 100cgs (Miki)

analytic (hom.)
TLM
PE

Atmospheric model

Meso-NH

MESO-NH

Meso-scale

Atmospheric research model of the french community (Meteo France)

After some developements:

Realistic and accurate results

http://mesonh.aero.obs-mip.fr/

Case of study

Presentation

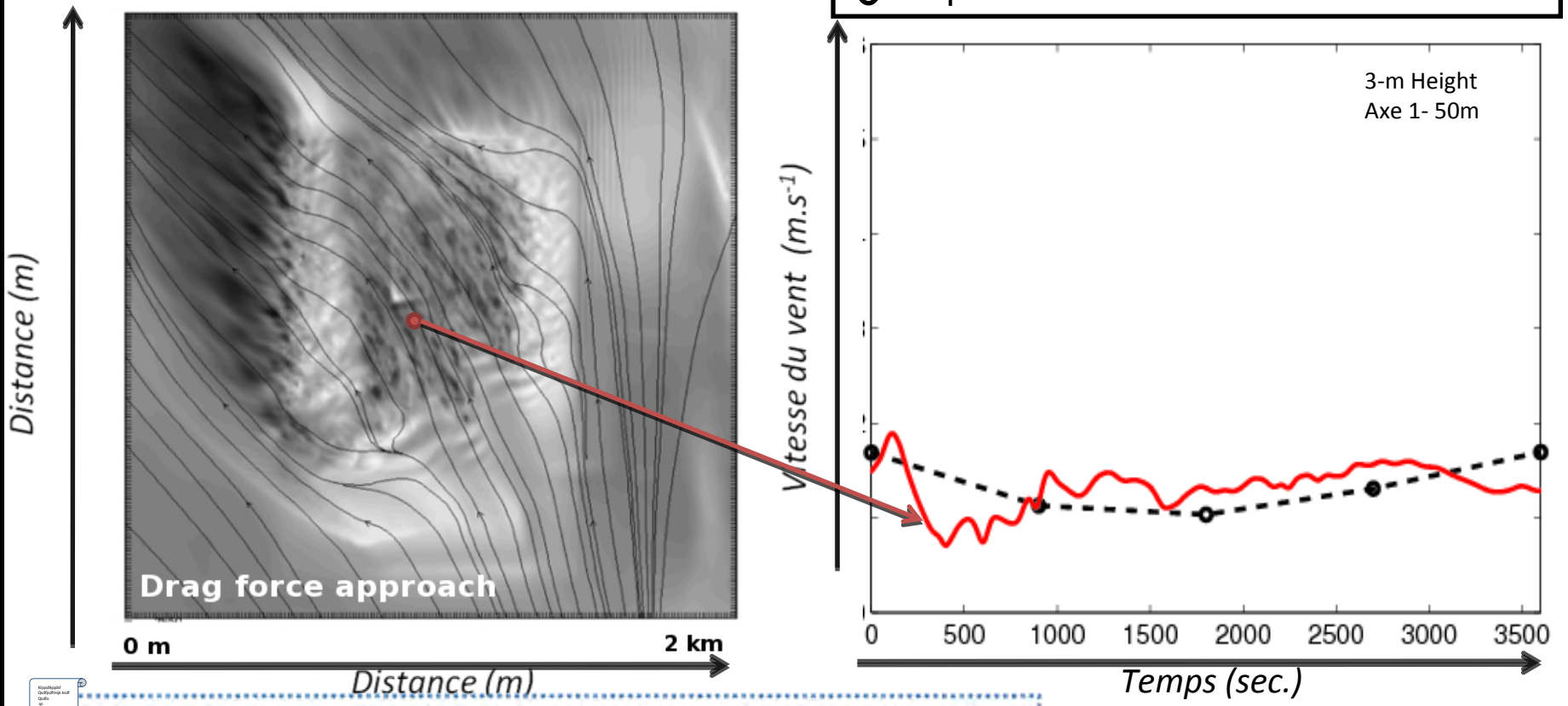
- Flat ground
- Stationnary source
- Observations period: 3 months
- Important measure systems
- Close to a national meteo station

Experimental campaign:
Lannemezan 2005

F. Junker et al., « *Meteorological classification for environmental acoustics* >> - ICA 2007

Meso-NH

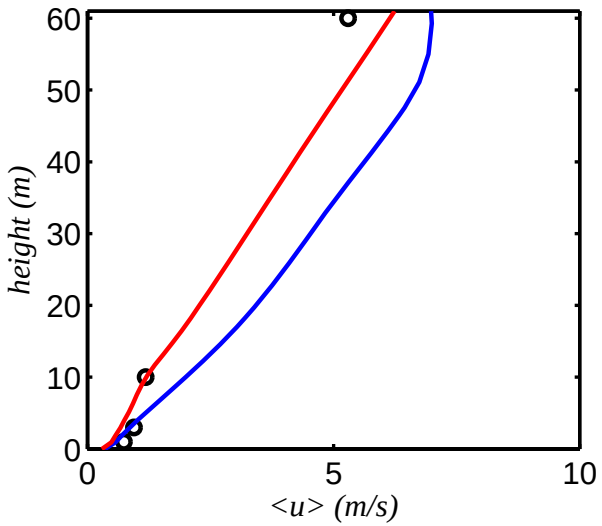
Results example



P. Aumond et al. *"Large-Eddy Simulations on the Effects of Drag Force of Trees: A real case study"* - 19th Symposium on Boundary Layers and Turbulence, 2010

Meso-NH

Results examples



Meso-NH

Experience

. 15 min averaged experiments and model fields

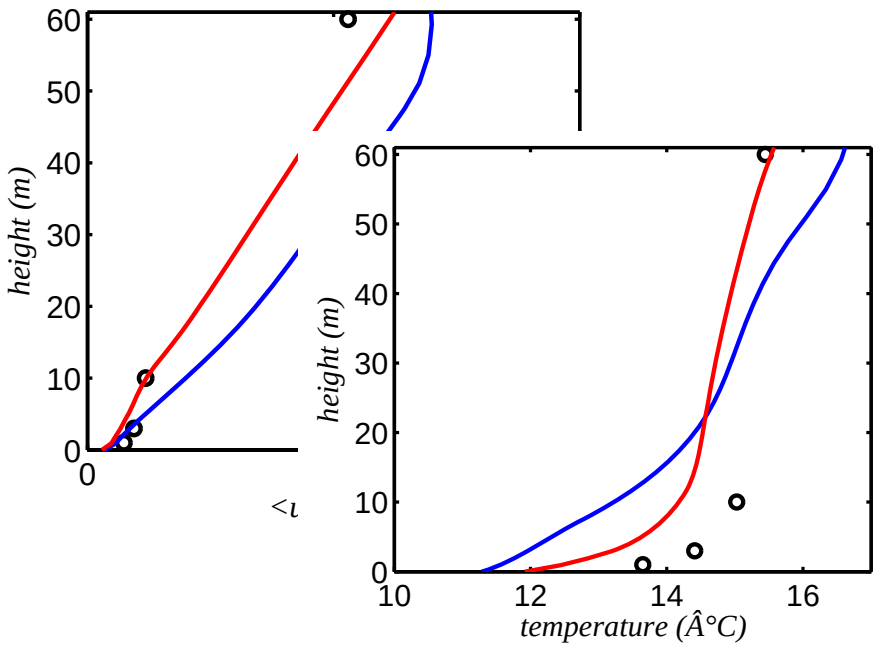
. Space averaging over the experimental zone (300m*300m)

. LES simulations 2*1m resolution

P. Aumond et al. *"Large-Eddy Simulations on the Effects of Drag Force of Trees: A real case study"* - 19th Symposium on Boundary Layers and Turbulence, 2010

Meso-NH

Results examples

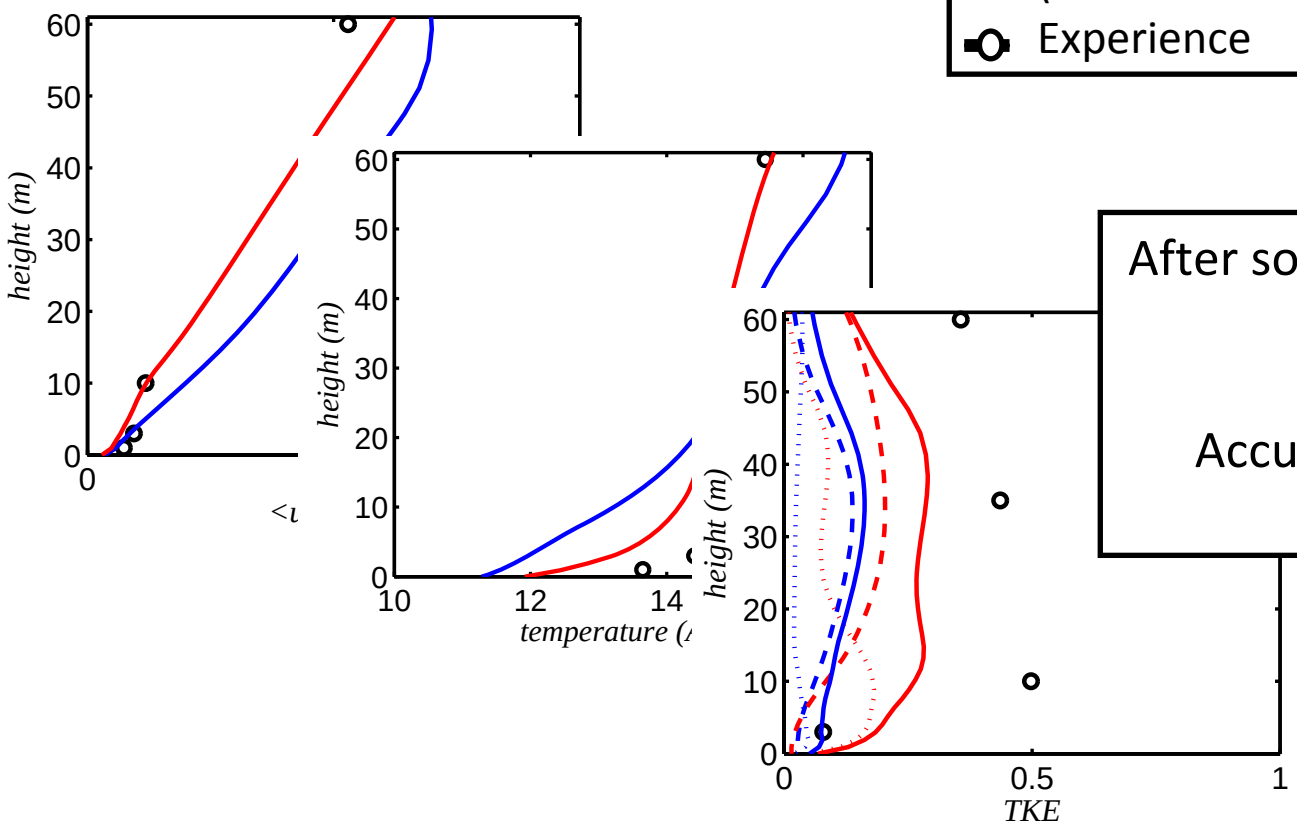


Meso-NH
(LES simulations 2*1m resolution)
Experience

P. Aumond et al. *"Large-Eddy Simulations on the Effects of Drag Force of Trees: A real case study"* - 19th Symposium on Boundary Layers and Turbulence, 2010

Meso-NH

Results examples



After some devellopements

...

Accurate and realistic results

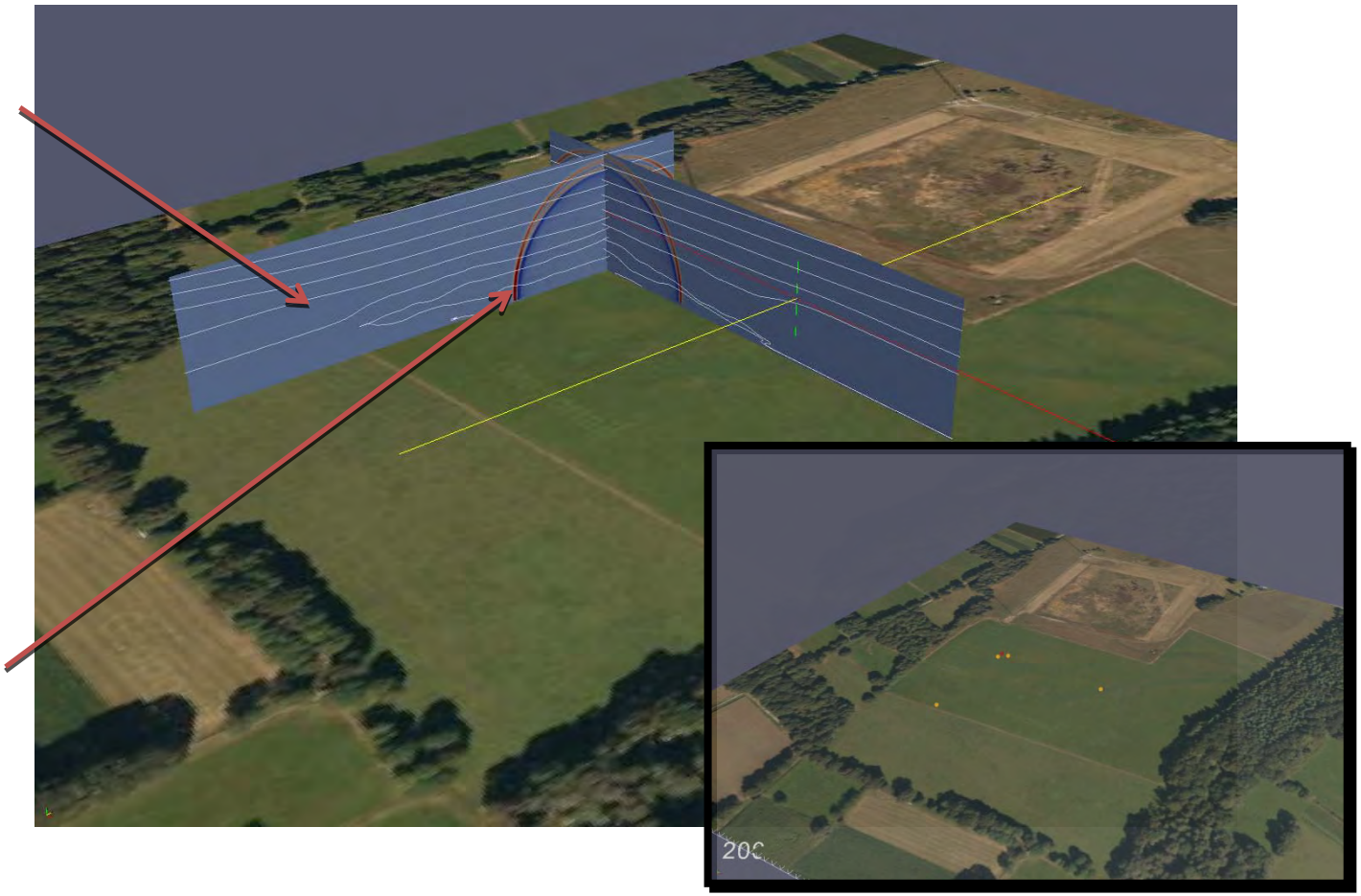
P. Aumond et al. *"Large-Eddy Simulations on the Effects of Drag Force of Trees: A real case study"* - 19th Symposium on Boundary Layers and Turbulence, 2010

Coupling

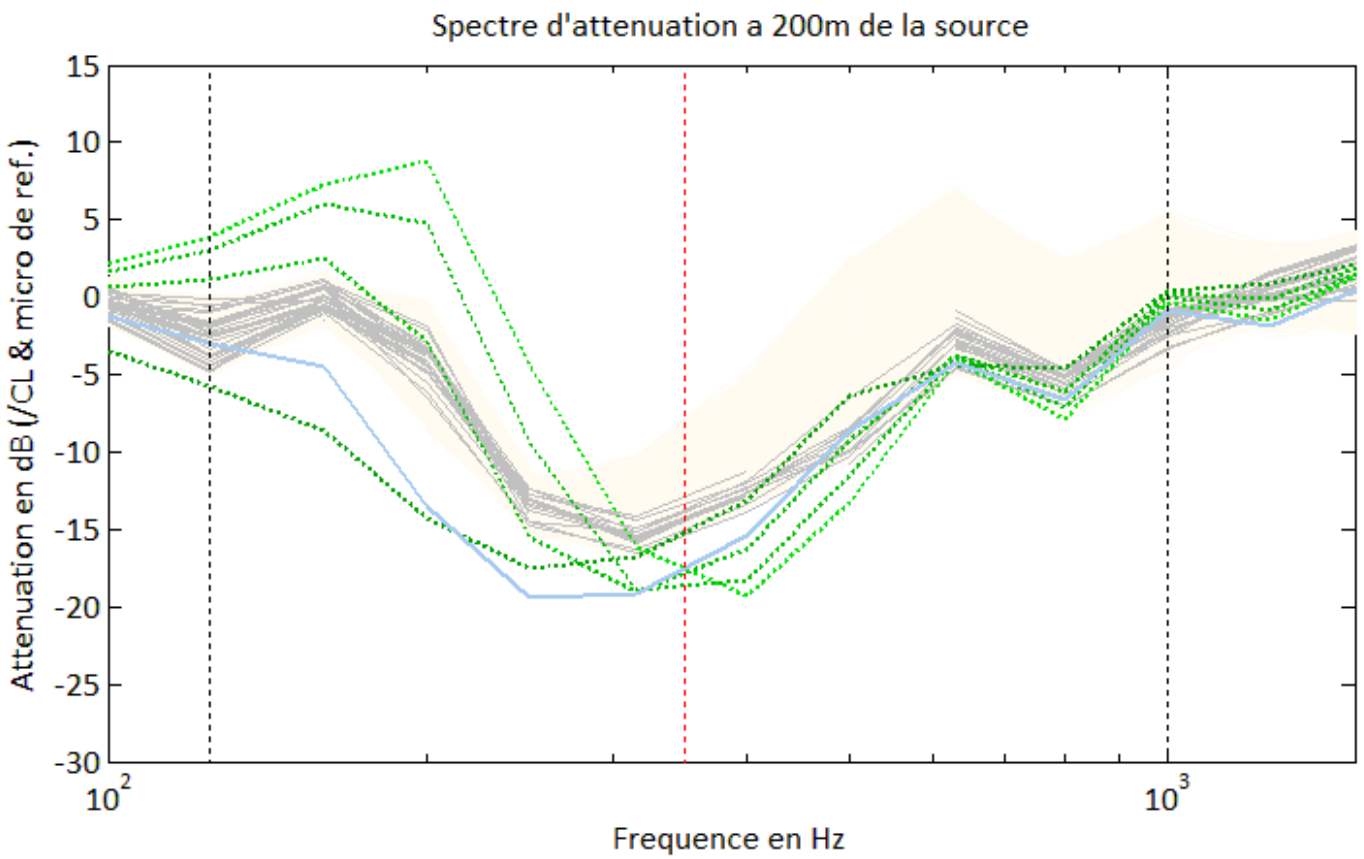
Presentation

Frozen meteorological conditions

2D wave propagation



Results


experience (tout *clair*, hom. *foncé*)
experience (16-06-2005)
tlm (16-06-2005)
Spectre d'attenuation a 200m de la source
Attenuation en dB (/CL & micro de ref.)
15
10
5
0
-5
-10
-15
-20
-25
-30
10^2
10^3
Frequence en Hz

Conclusions / perspectives

- **Meso-NH**
- **TLM validation :**
  - **Num. : meteo + ground**
  - **Exp. : Good agreement with Lannemezan 2005 data < 800 Hz**

- **Extended validation with more experimental samples**
- **Use this model to study more complex situation…**
  - **LTMS**
  - **Urban modelling**

Thank you

-

Questions ?

Pierre Aumond

3rd year PhD-Thesis

17th may 2011

GDR Visible - Bron

« […] our observations this day prove the very great effect which upward refraction has on the distances at which sounds can be heard. »

Pr. O. Reynolds & Pr. Stokes - 1876

Perspectives

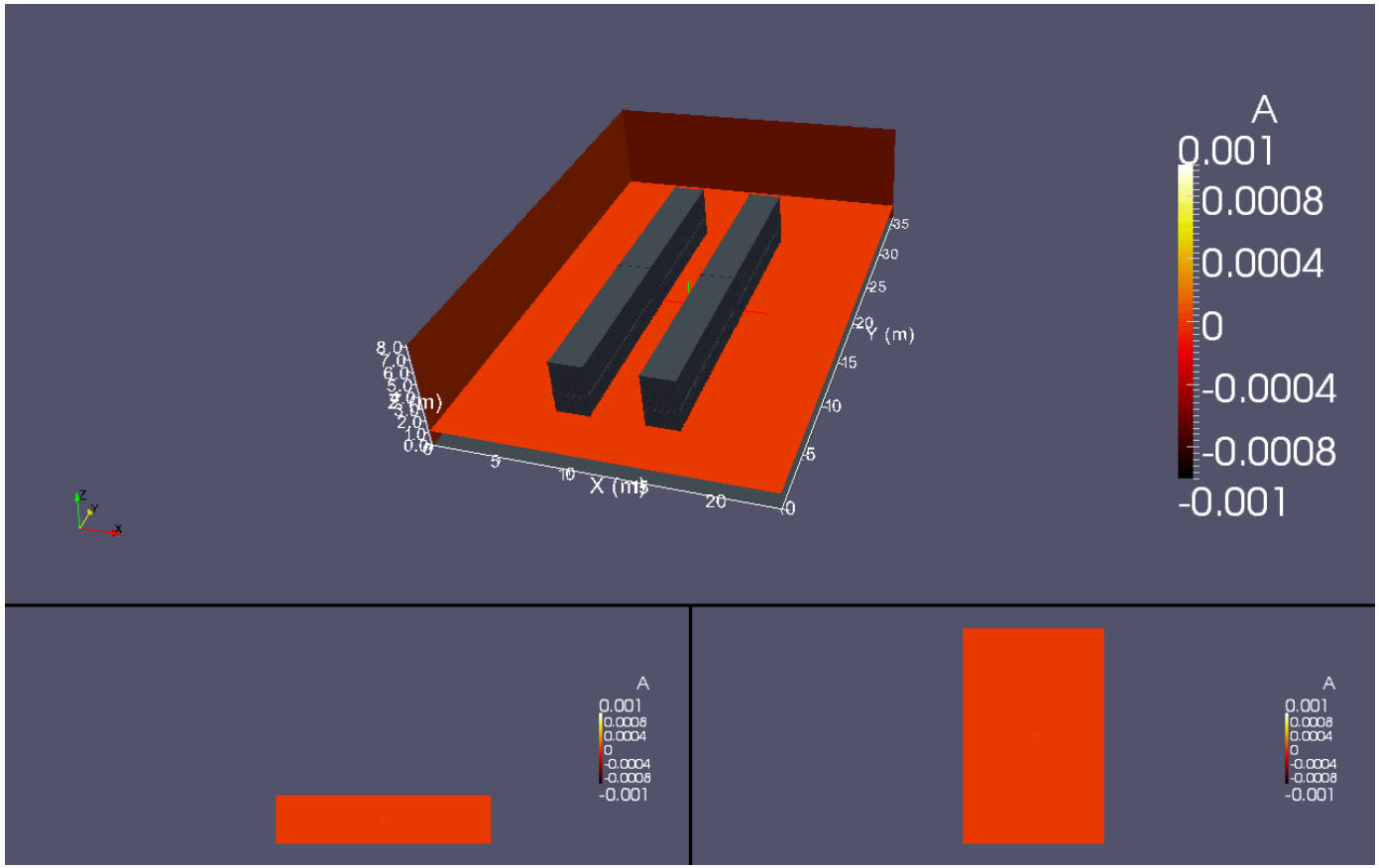
LTMS

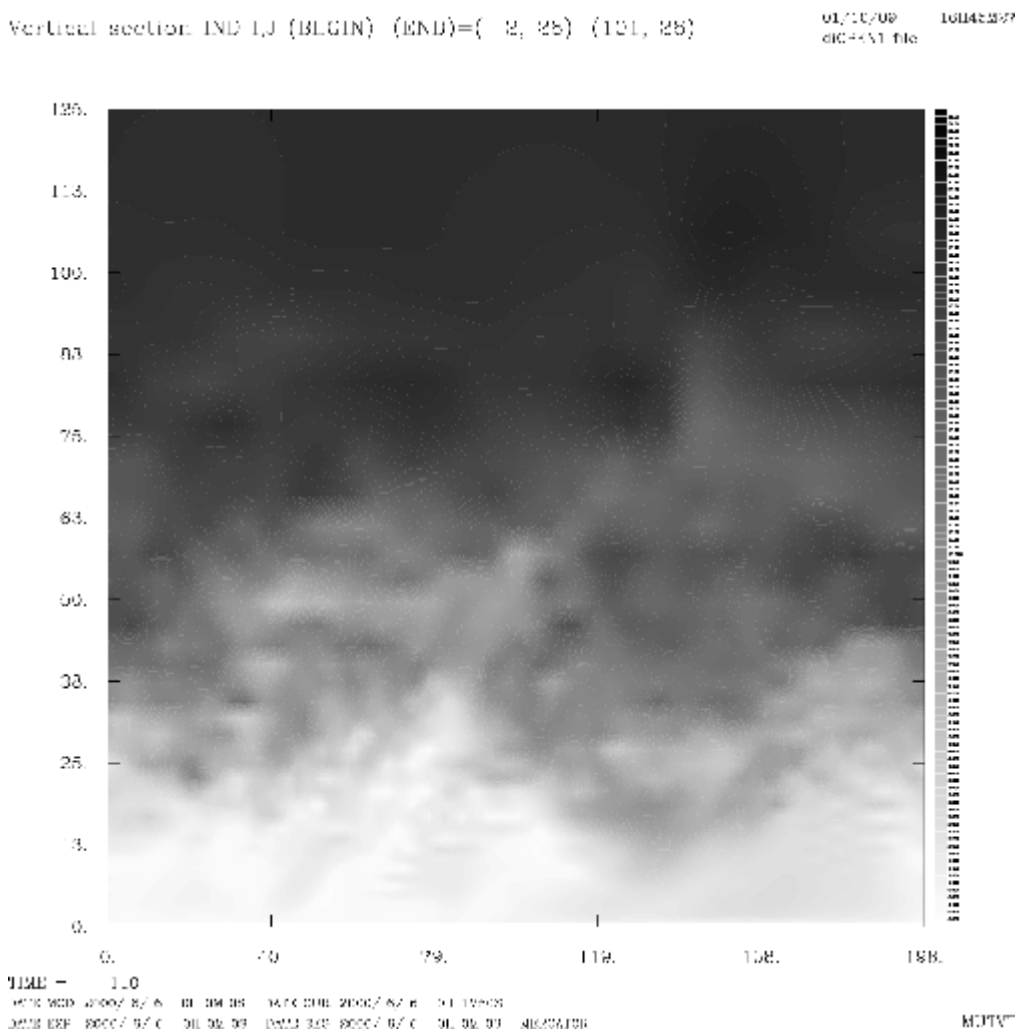
- Complex topography
- Real sources (highway, railroad, …)
- Monitoring meteo/acoustic aquisition over several years (since 2002)

Experimental campaign:
Long Term Monitoring Station

http://www.lcpc.fr/english/presentation-209/human-and-financial-resources/lcpc-exceptional-testing-229/

Urban modelling




Vertical section: IND I,J (BEGIN) (END)=(2, 25) (131, 25)
01/10/09 16H48M37
GRADS file
125.
113.
100.
88.
75.
63.
50.
38.
25.
13.
0.
0.
79.
158.
TIME = 1.0
MOTV