Atmospheric sound propagation

Focus on : *Field measurements (& uncertainties)*

14 june 2018

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Unité Mixte de Recherche en Acoustique Environnementale

www.umrae.fr

Who am I ? (1/3)

Positions

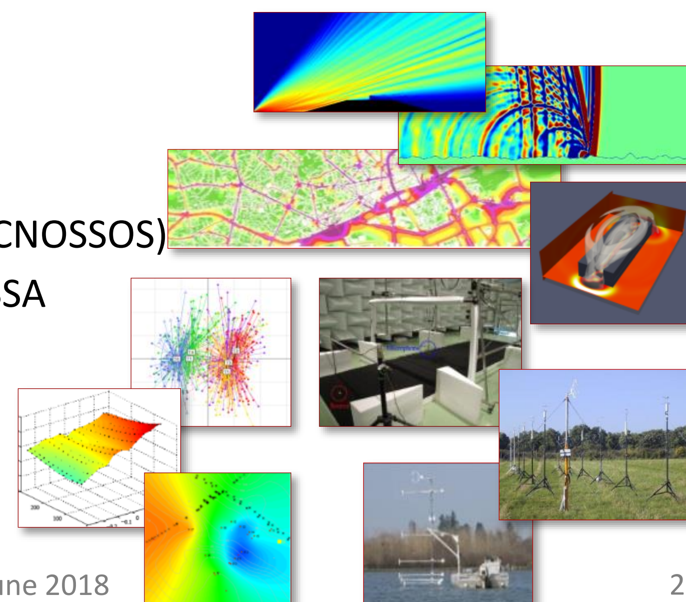
- 1999 : PhD Thesis on "Numerical simulation of road noise propagation in inhomogeneous medium and complex ground" (using PE)
- 2000-2001 : responsible of R&D teams as a "research engineer"
- Since 2002 : researcher at Ifsttar (PHY, NUM, STAT, EXP) >> coordination of numerous experimental campaigns (in situ, 5-20 people, 3 days to 3 months)

Animation and coordination

- Organisation of congresses, sessions and scientific days (GdR CNRS, SFA, CIDB, Ifsttar, etc.)
- Responsible of PRF « Urban sound environment » (ESU) at Institut de Recherche en Sciences et Techniques de la Ville

Methodological approaches

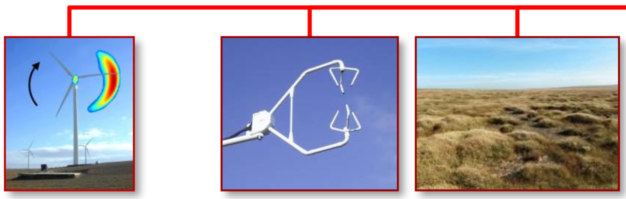
- **PHY** : long range sound propagation
- **NUM** : ref. models (PE, TLM) and simplified models (NMPB, CNOSSOS)
- **EXP** : in situ measurements (acoustic/meteo/impedance) + SSA
- **STAT** : (geo)statistical analysis
- Holistic and interdisciplinary approaches

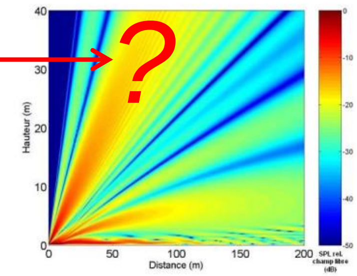


Who am I ? (2/3)

Topics

- Road traffic noise, urban sound environment
- >> wind turbine noise (on/off shore)
- Atmosphere physics (LES & CFD)
- Emission + propagation >> uncertainties
- Env. impacts (indicators, health, biodiversity)





Research activities and expertise

- Productions : reports, publications, presentations, etc.
- Peer review : JASA, Applied Acoustics, etc.
- Transfer to engineering (« standards »)
  - AFNOR S30J / GT : 31-110 (météo), 31-115 (incertitudes), 31-114 (éolien), 31-190 (aérien), 31-010 (indicateurs), etc.
  - AFNOR S30M / GT : 31-085 (route), 31-088 (fer), 31-130 (cartographie), 31-133 (calcul), 31-185 (long terme), etc.
  - BNSR / CNEA, CEN, ISO

Partnerships

- Within national and european projects : PdL, PREDIT, ADEME, ANSES, ANR, DEUFRAKO, PCRD, etc.
- Academic partnerships (institutes, academic colleges)………………. universities…………… and industry

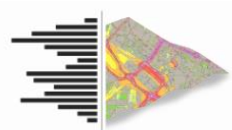
Who am I ? (3/3)

Formation

- Initial (Licence et Master, Pro et Recherche):
  - Université du Maine (ENSIM, LAUM), Ecole Centrale de Nantes (ECN)), Ecole des Mines de Nantes, ParisTech, etc.
- Continue: Ponts Formation

Tools, methods, hardware and software


- Prototype « MIAME » (partnership Ifsttar/Cerema)


- Methods and sofwares (*open source*)
  http://noise-planet.org/fr/noisemodelling.html



- Smartphone app. Android (*crowdsourcing*)
  http://noise-planet.org/fr/noisecapture.html

Valorisation and dissemination


http://ltms2002-2007.ifsttar.fr

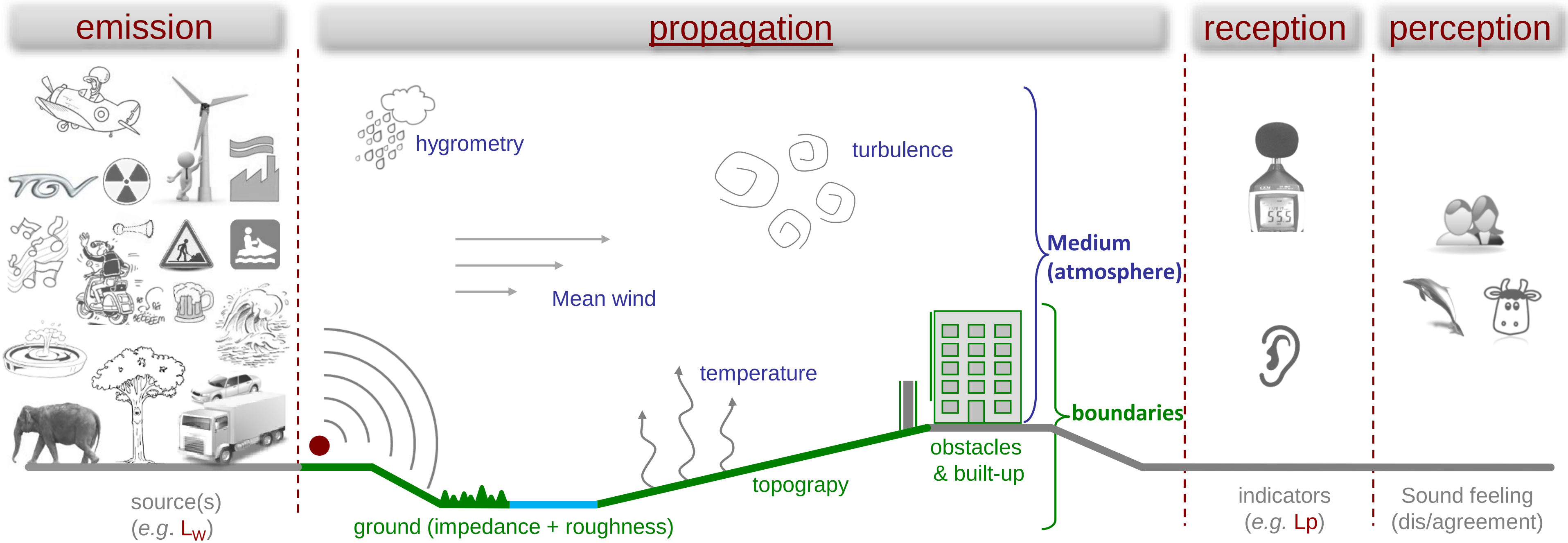

http://deufrabase.ifsttar.fr

- Reference databases, *e.g.* LTMS, DEUFRABASE


http://www.plante-et-cite.fr

- Methodologic guides, Technical documents for *end-users* (collectivities, urbanists, etc.)

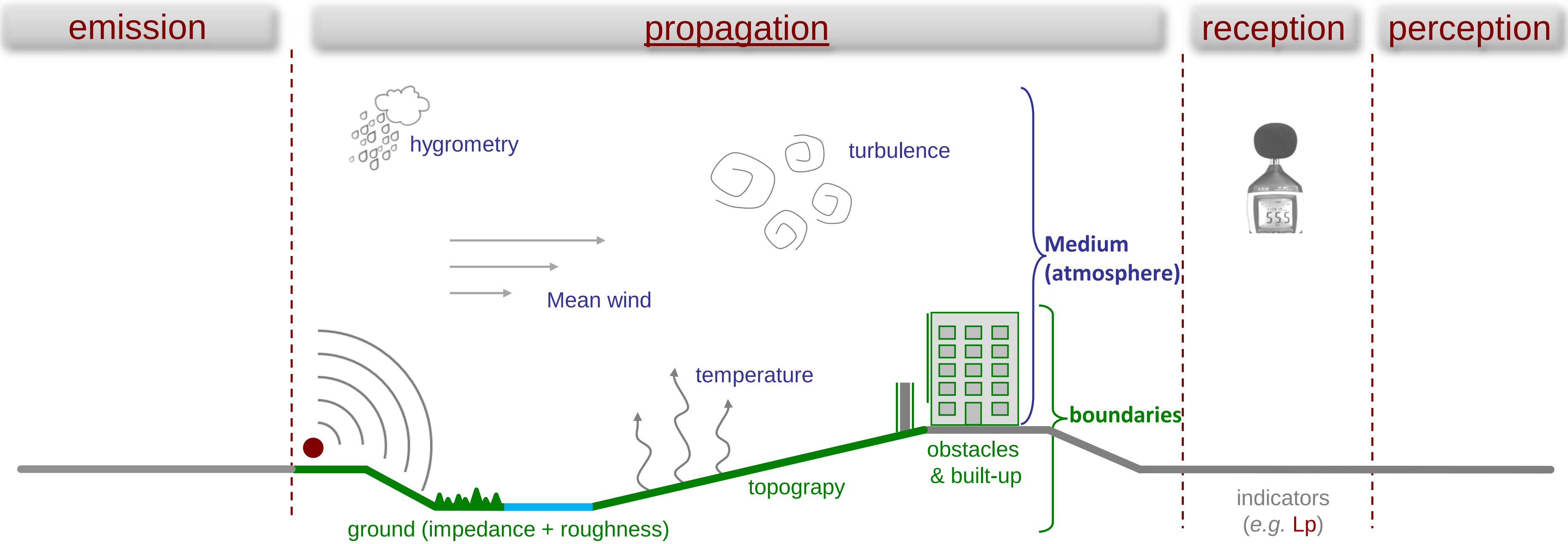
Foreword



$$L_p = L_W \pm \Delta_{propagation} = L_{source} \pm \Delta_{medium} \pm \Delta_{boundaries}$$

$$= L_{source} \pm \Delta_{div} \pm \Delta_{atmos} \pm \Delta_{wind} \pm \Delta_{temp} \pm \Delta_{turb} \pm \Delta_{ground} \pm \Delta_{topo} \pm \Delta_{obst} \pm \dots$$

Foreword


emission
propagation
reception
perception
hygrometry
turbulence
Mean wind
Medium
(atmosphere)
temperature
boundaries
obstacles
& built-up
topograpy
ground (impedance + roughness)
indicators
(e.g. Lp)

Contents

> **Foreword**

- Noise emission
- *Noise propagation : influence of boundaries characteristics and medium (atmosphere / micrometeo) conditions*
- Noise reception/perception

> **Examples in *open field*** (without obstacles, flat or complex topography)

- Laon_1999
- Harmonoise_2002-2004
- Lannemezan_2005
- Sonic_2007
- LTMS_2002-2007
- Fouché_2013
- Ifsttar_2011
- PhD Thesis O. Faure (2014)
- PhD Thesis B. Kayser (2017) >> LRSP
- MIAME prototype (impedance measurement)






> **Examples in *urban medium*** (multiple sound sources + obstacles >> « diffuse field »)

- Tours_2002
- EM2PAU_2012
- VegDUD_2014
- EUREQUA_2016
- CENSE_2018






> **Conclusion and outlooks**

- Variability (deterministic) + uncertainty (stochastic)
- SPL dispersion in space
- SPL dispersion in time
- Other indicators (EDT, TR, etc.)
- Influent parameters (observables) for outdoor sound propagation
- Input data for numerical predictions
- >> D. Écotière lesson on “Uncertainties and variability”…





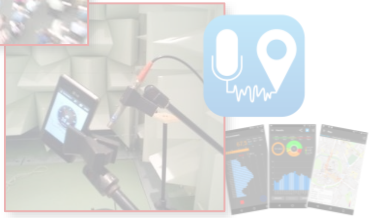
Contents





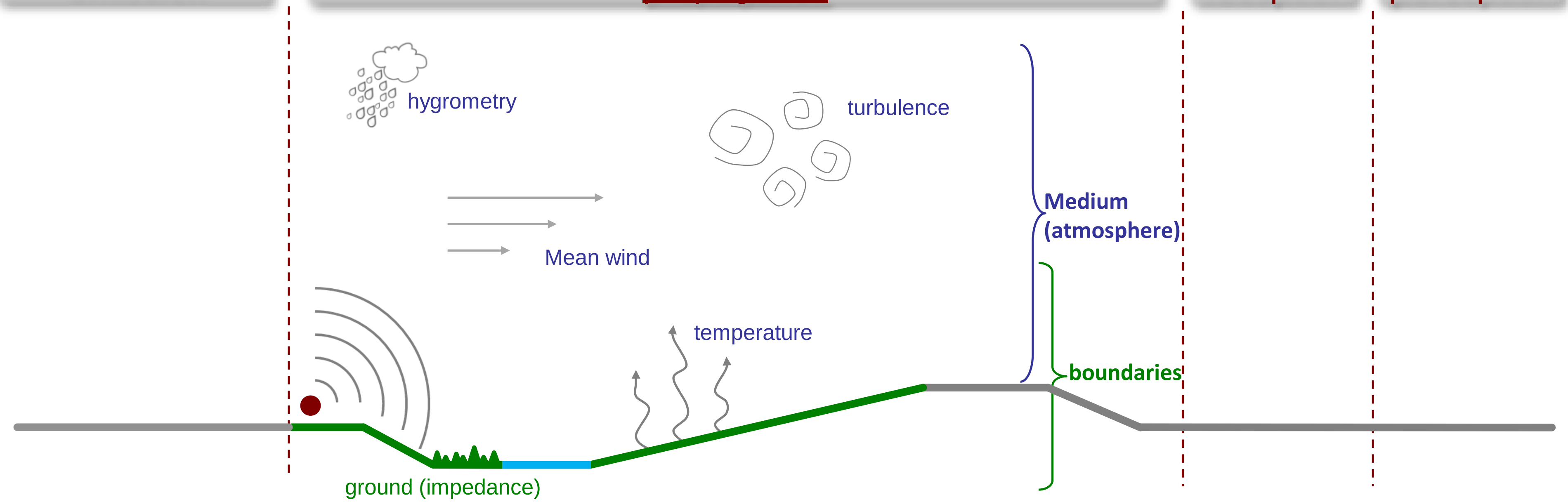





Lannemezan_2005

emission | propagation | reception | perception



Lannemezan_2005

- **Partnership**
- ***Relative* influence of propagation parameters (ground imped. + meteo)**
- [**Numerical part : ref. models (PE) and engineering models (NMPB)**]
- ***Experimental part* : measurements campaign at Lannemezan (F-65)**
  - → experimental site : quiet and almost flat (no topography)
  - → Different weather conditions during a “typical” day (+ Météo-France station)
  - → 3 weeks period with maximum number of sensors and continuous controls
  - → After 3 weeks until the end (3 months): less sensors and periodic controls
  - → “point source” (dodecaedric) – controlled spectrum and amplitude
  - → Refined sampling (time + space) for data acquisition : “monitoring”
  - → about 60 acoustical sensors and 70 meteo sensors (!)
  - → raw data >> post-processing >> validated database >> analysis…


Lannemezan
H^{tes}-Pyrénées
(65)
Paris
Milano
Lannemezan
N
W
E
S
Image © 2005 MDA EarthSat
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(Lab

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Atmospheriques
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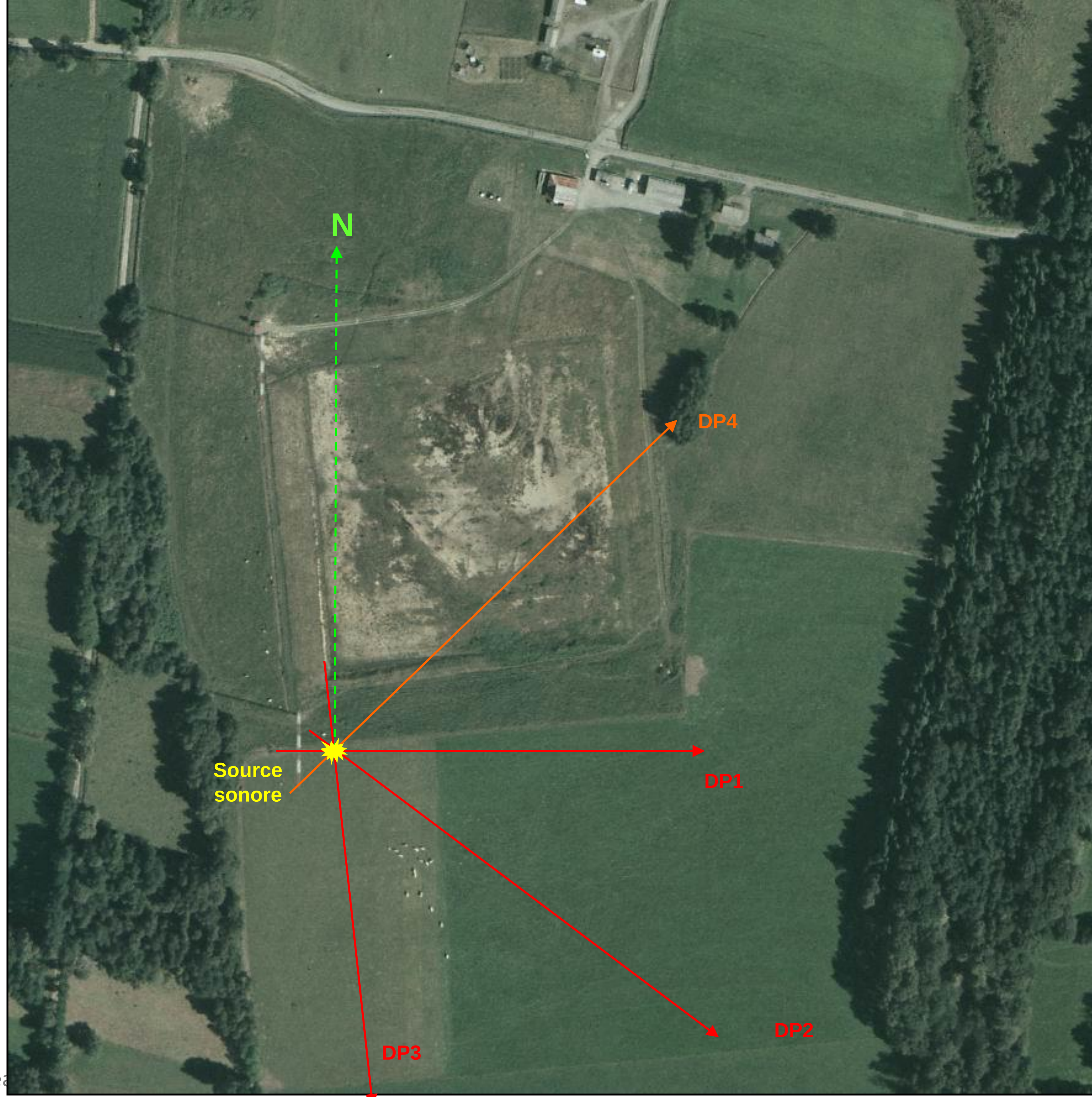
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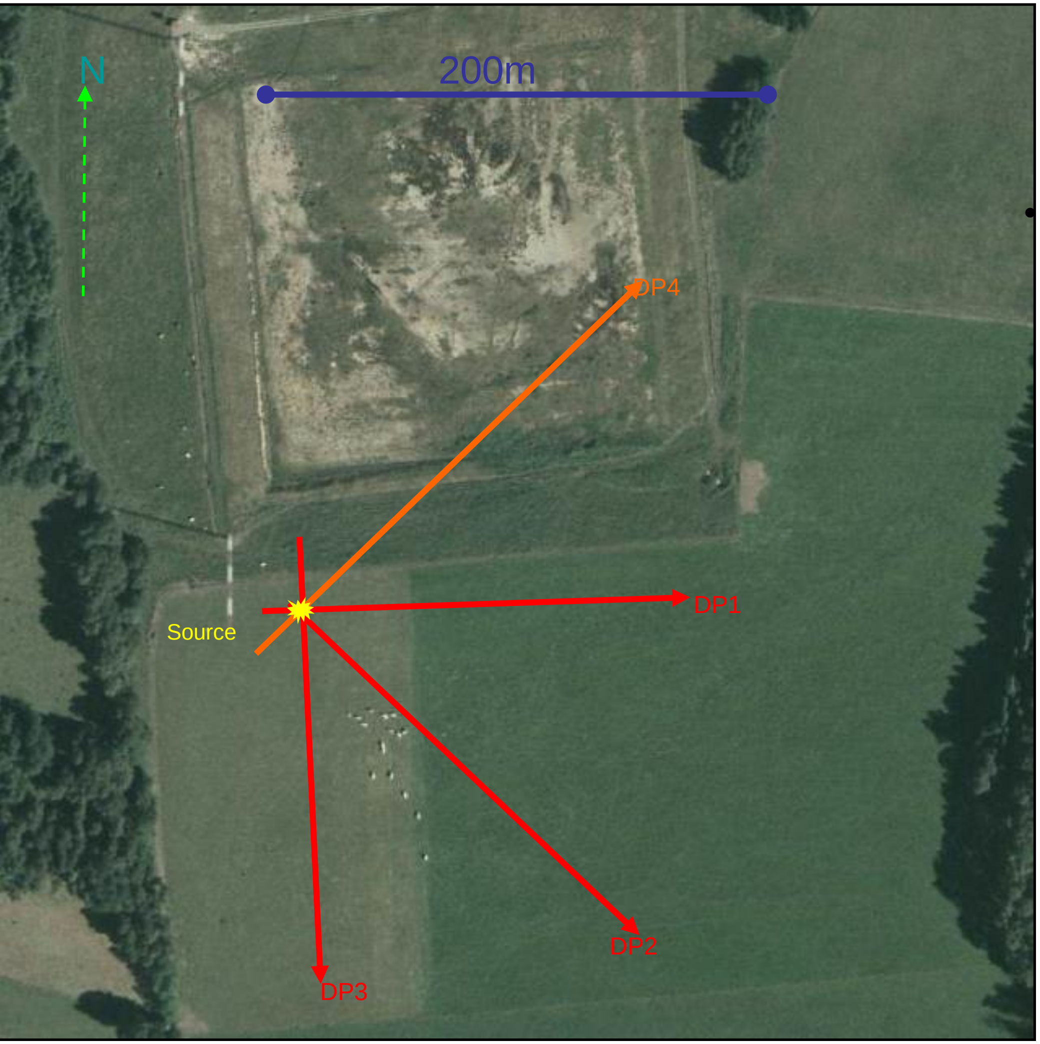
DP4
DP1
Source
sonore
DP2
DP3

Lannemezan_2005

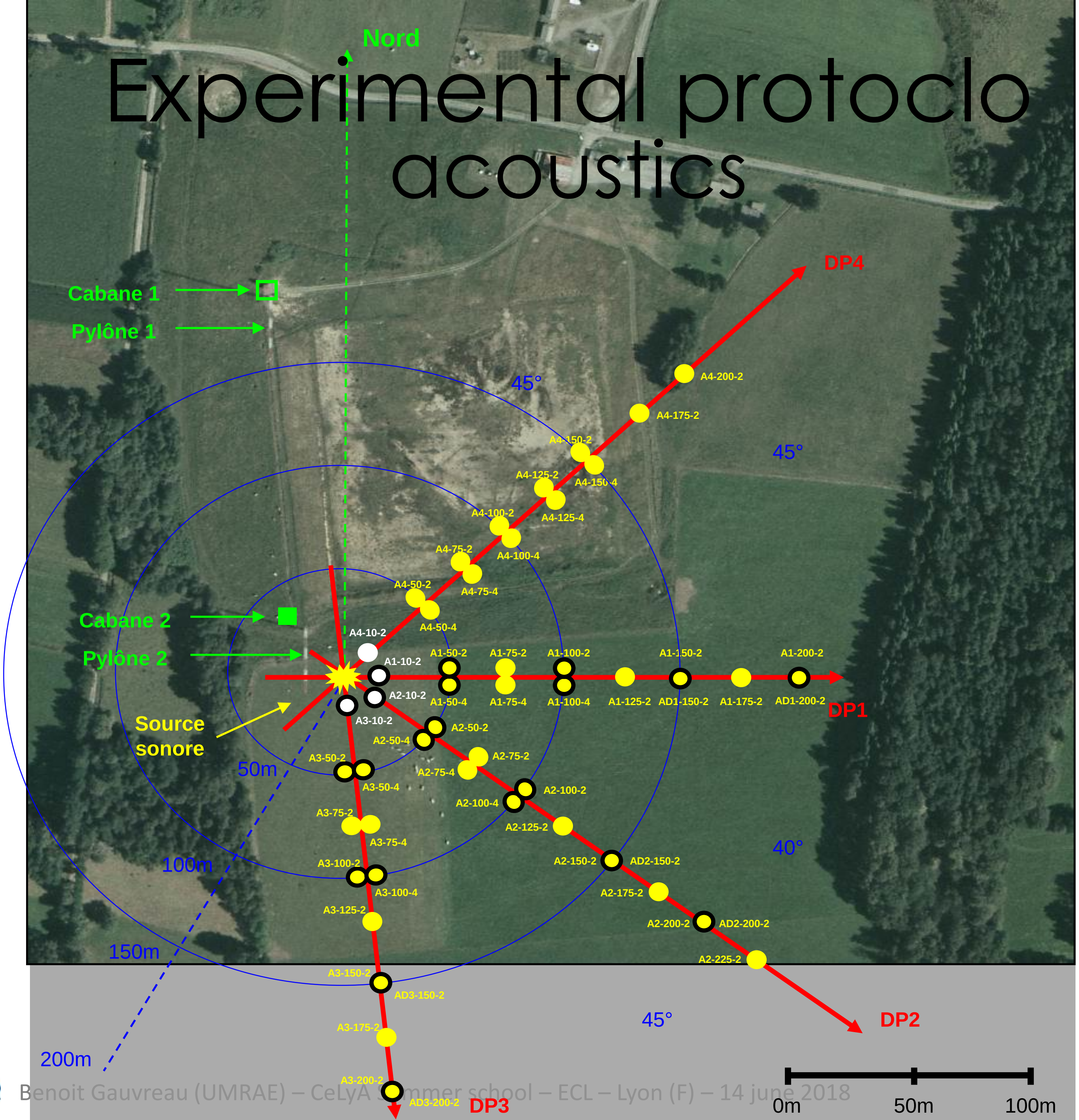


- Omnidirectionnal sound source (12 LS) ; 108 dB(A) - Pink noise ; Switched Off 5 min every 4 hours (background noise)

50 microphones along 4 lines ($DP_{1,2,3,(4)}$) every 25 meters from 50 m to 200m from the source + reference at 10m

- A 3D ultrasonic anemometer at 3m high and 125m from the source in each direction
- Two 10m meteorological towers (WS, WD,T at 1m, 3m and 10m) at 75 and 175m from the source in each direction
- A 60 m high meteorological tower with 3 ultrasonic anemometers, 3 temperature sensors and 3 humidity sensors at 200m northbound from the source
- Space and time monitoring of ground impedance

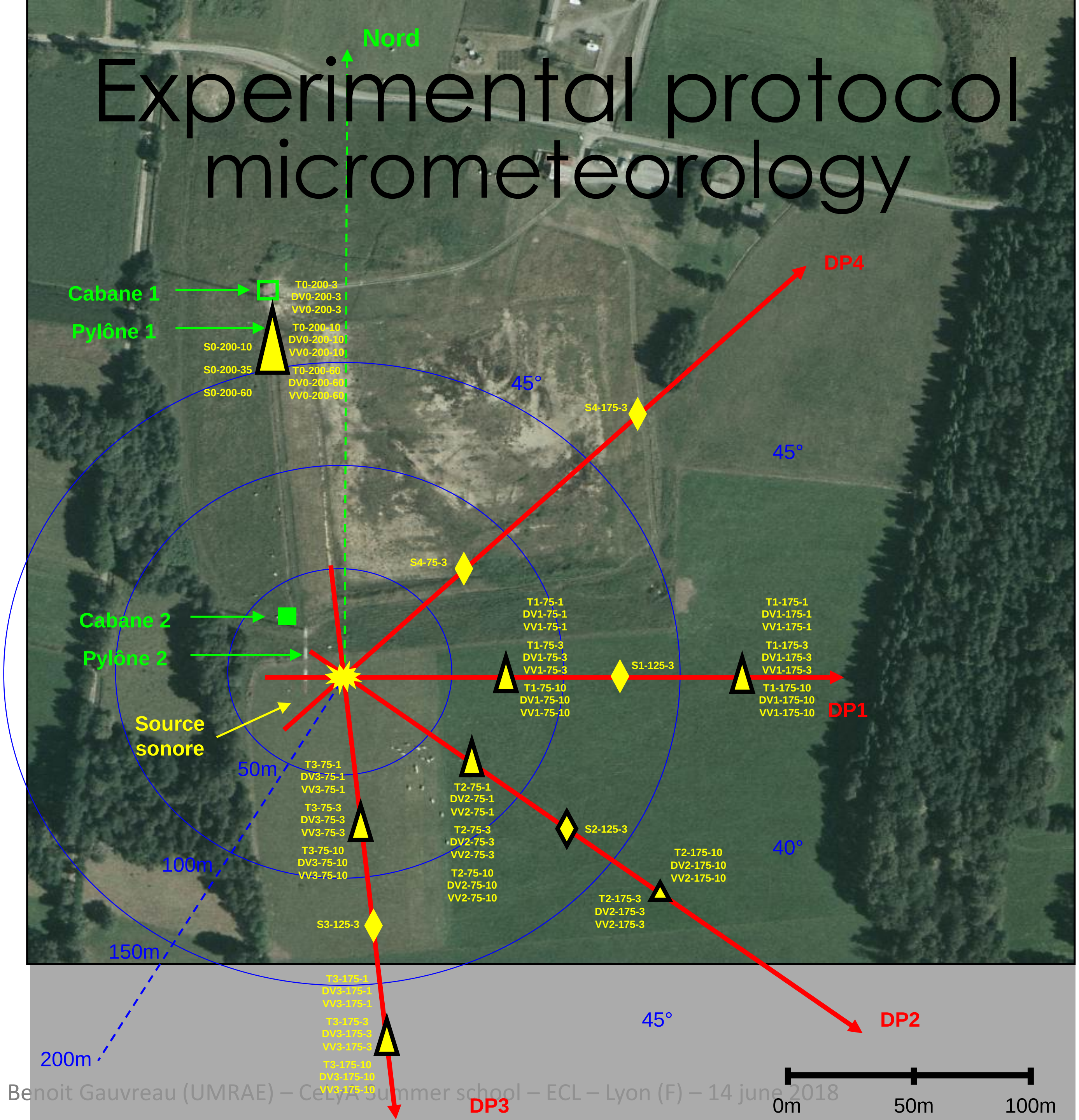
Experimental protoclo acoustics



▪ Sound measurements

- $L_{eq\ 1\ seconde}$ – 1/3 Octave (50 Hz/5000Hz)
- Audio monitoring
- Devices :
  - Source(s) : B&K omnidirectionnelle (L_w=108 dB(A))
  - Microphones : B&K, 01dB
  - Systèmes d'acquisition : SALTO, PULSE (19 voies), SYMPHONIE, PAK (16 voies), SIP95TR, B&K 2260, B&K 2250

Experimental protocol micrometeorology



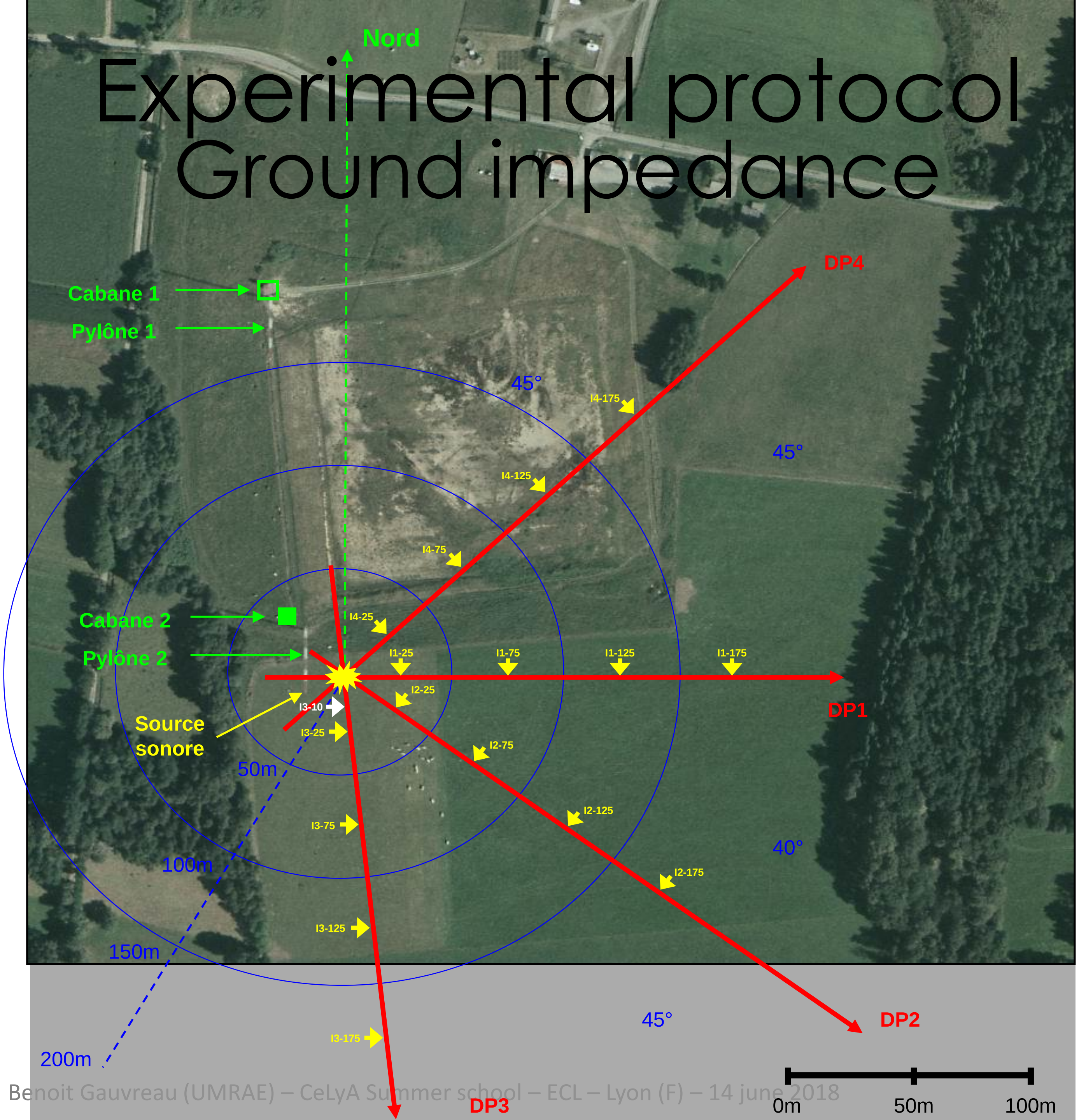
Lannemezan_2005

▪ Meteo measurements

- **Mean profiles of sound celerity**
  - Classical « slow » devices (10m meteo towers)
    - T, VV et DV à 3 hauteurs
    - Procédure « best fit » >> profils moyens : **dc/dz (fit)**
    - Procédure « Monin-Obukhov » >> profils moyens : **dc/dz (MO)**
  - 3D sonic anemometers
    - U*, T* et $1/L_{MO}$ (1 hauteur) >> loi de similitude de M-O : **dc/dz (turb)**
    - Mesure directe de la célérité du son à 3 hauteurs >>profils moyens : **dc/dz (dir)**

- **Atmospheric turbulence characteristics**
  - 3D sonic anemometers
    - Variances T, VV et DV (échantillonnage 20Hz) >> intensité turbulente
    - Valeurs moyennes sur la durée d'échantillons (1 à15 min) >> spectre (échelle) de turbulence

Experimental protocol
Ground impedance

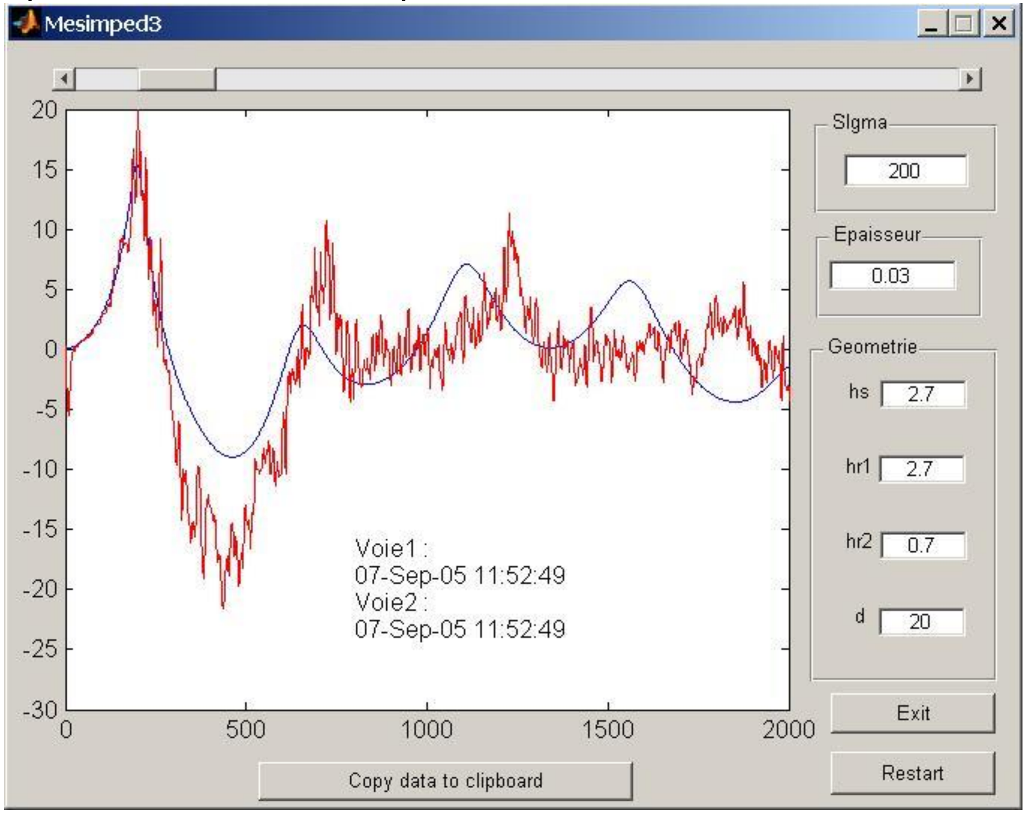


Lannemezan_2005

▪ Ground impedance measurements

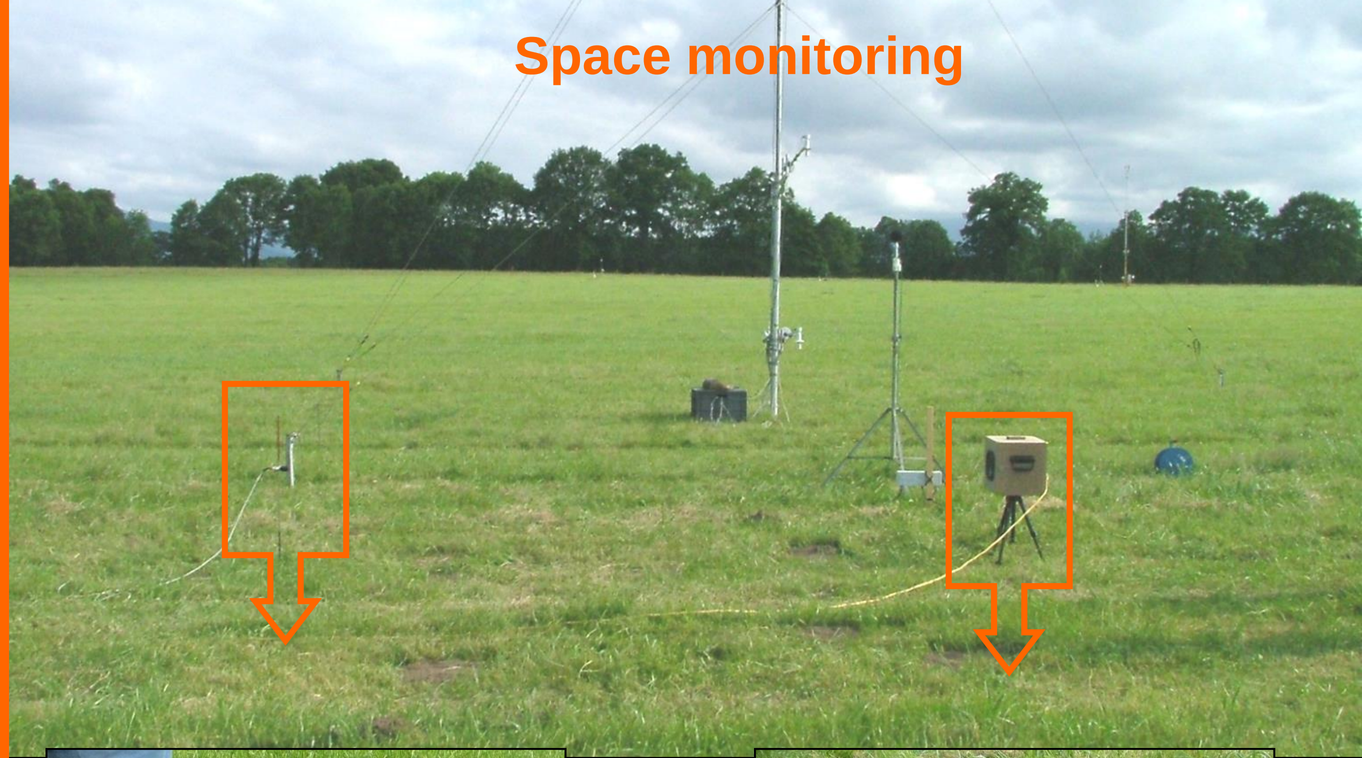
- **Space AND time variability**
  - –Enregistrement audio 2 voies toutes les 4 heures (point fixe)
  - –Mesures avec source dédiée + 2 micros (mesures en différents points réalisées fréquemment)

- **Principle :** trouver la valeur de la résistance au passage de l'air qui permet d'ajuster « au mieux » la différence de niveau entre les deux microphones



Time monitoring

Space monitoring



Lannemezan_2005

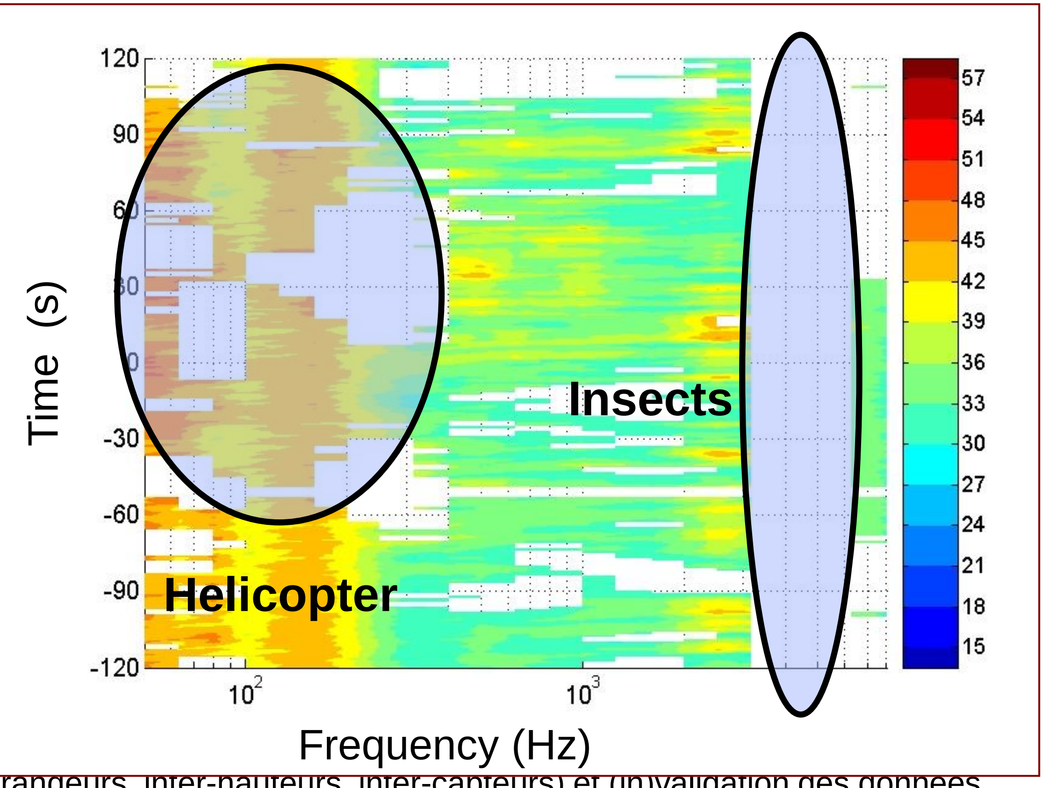
A few notes…

- 83 jours d'acquisition
- Jusqu'à 49 voies micros
- Jusqu'à 70 capteurs météo
- 22 personnes présentes sur le site à l'installation et une grande majorité durant 3 semaines (journal, événements sonores parasites)
- Suivi hebdomadaire sur place + à distance durant 3 mois
- Des km de câbles, coups de soleils, tiques, rustines, BBQ, *etc*…

Lannemezan_2005

▪ Data filtering and post-processing

- **Acoustic data**
  - –Filtrage des périodes de pluie, de vent
  - –Calcul des bruits de fond pour chaque
  - –Calcul des histogrammes pour l'ensem
  - –Filtrage des données par comparaison
  - –Recomposition 15 min (de 800 à 4000
- **Impedance data**
  - –Recalage du modèle et obtention des v
  - –Étude de l'influence de l'opérateur et de
  - –Détermination d'une tendance pour l'év



- **Meteo data**
  - –Vérification et (in)validation des donnée
  - –Calculs des moyennes 15min (∀ mâts/
  - –Calculs des gradients verticaux de célé
  - –Calculs des valeurs U* et T* à partir de
  - –Nouvelles vérifications croisées (inter-grandeurs, inter-hauteurs, inter-capteurs) et (in)validation des données
  - –Définition et application d'un critère de qualité des échantillons 15 min (en cours)

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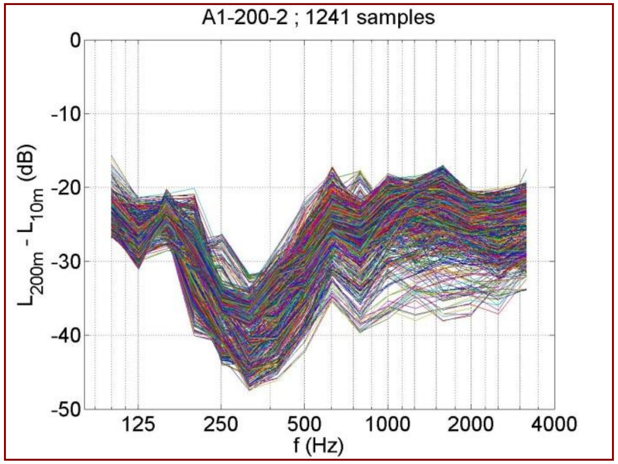
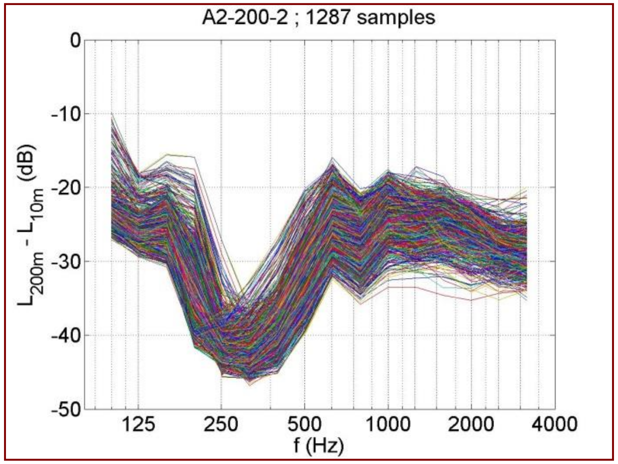
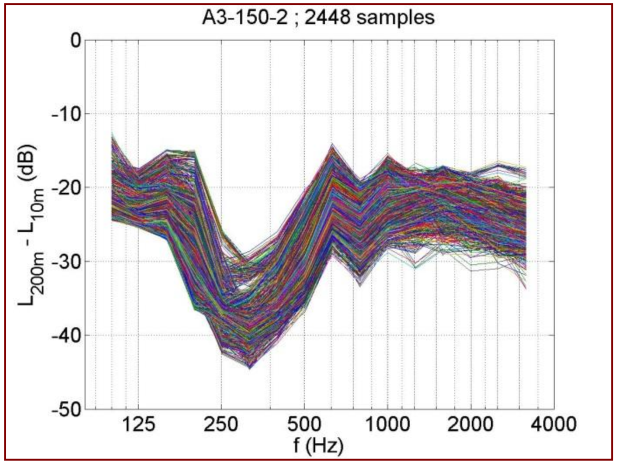
▪ Experimental results: acoustical data

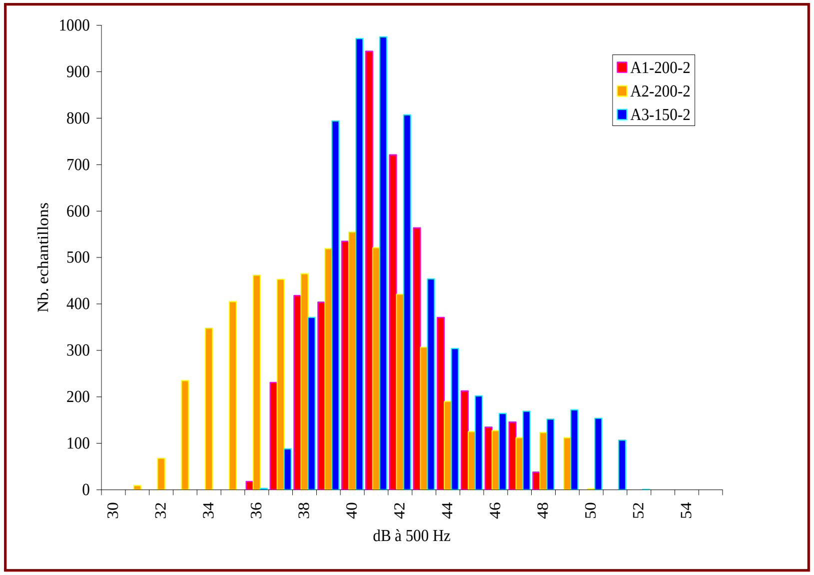
- **Spectrum dispersion**







- **Histograms**



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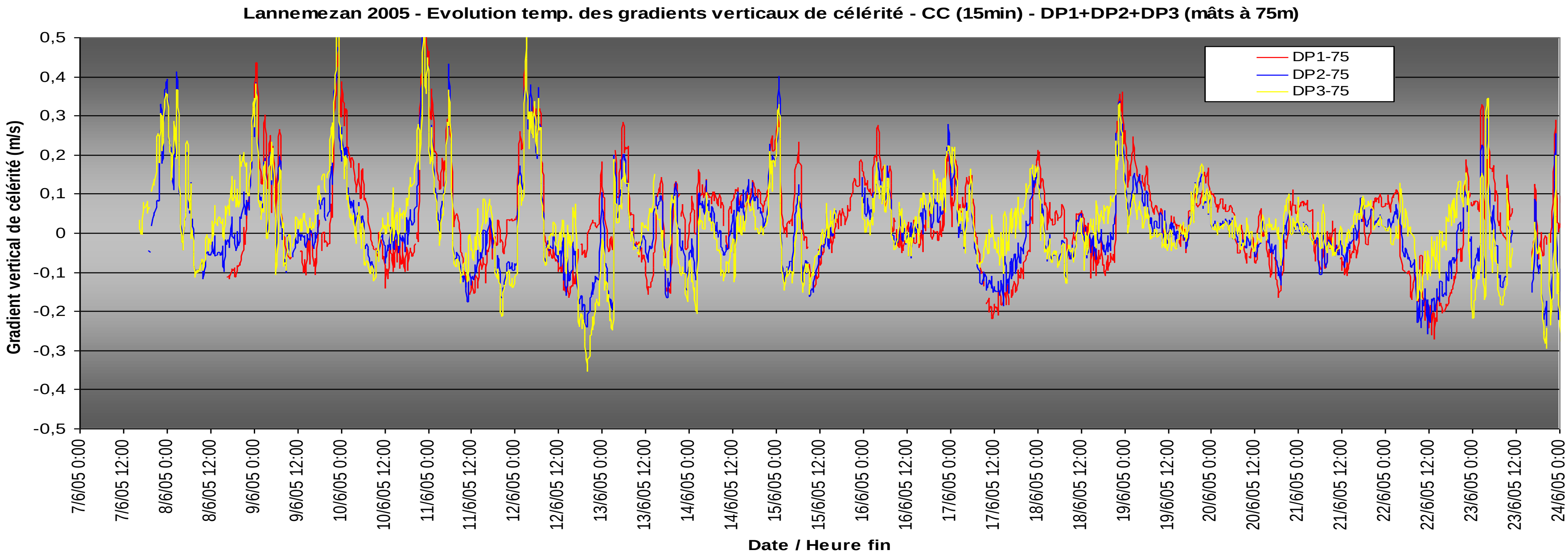
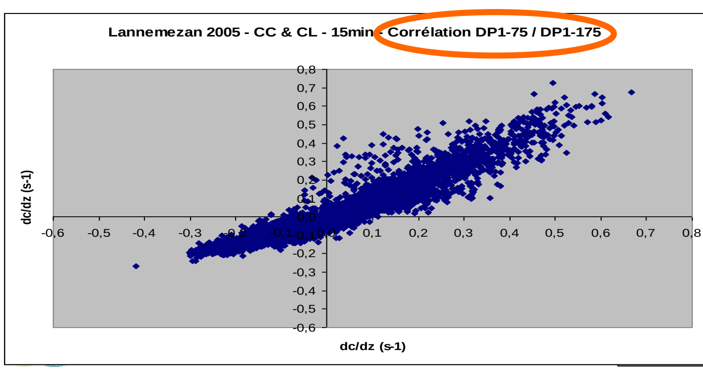
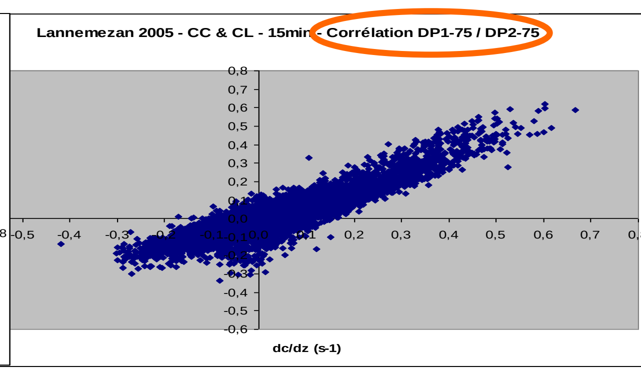
▪ Expérimental results : meteo

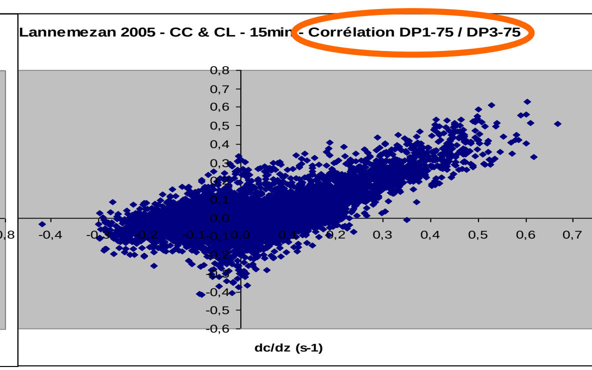
- **Times series**



- **Spatial correlation (DP1,DP2,DP3)**







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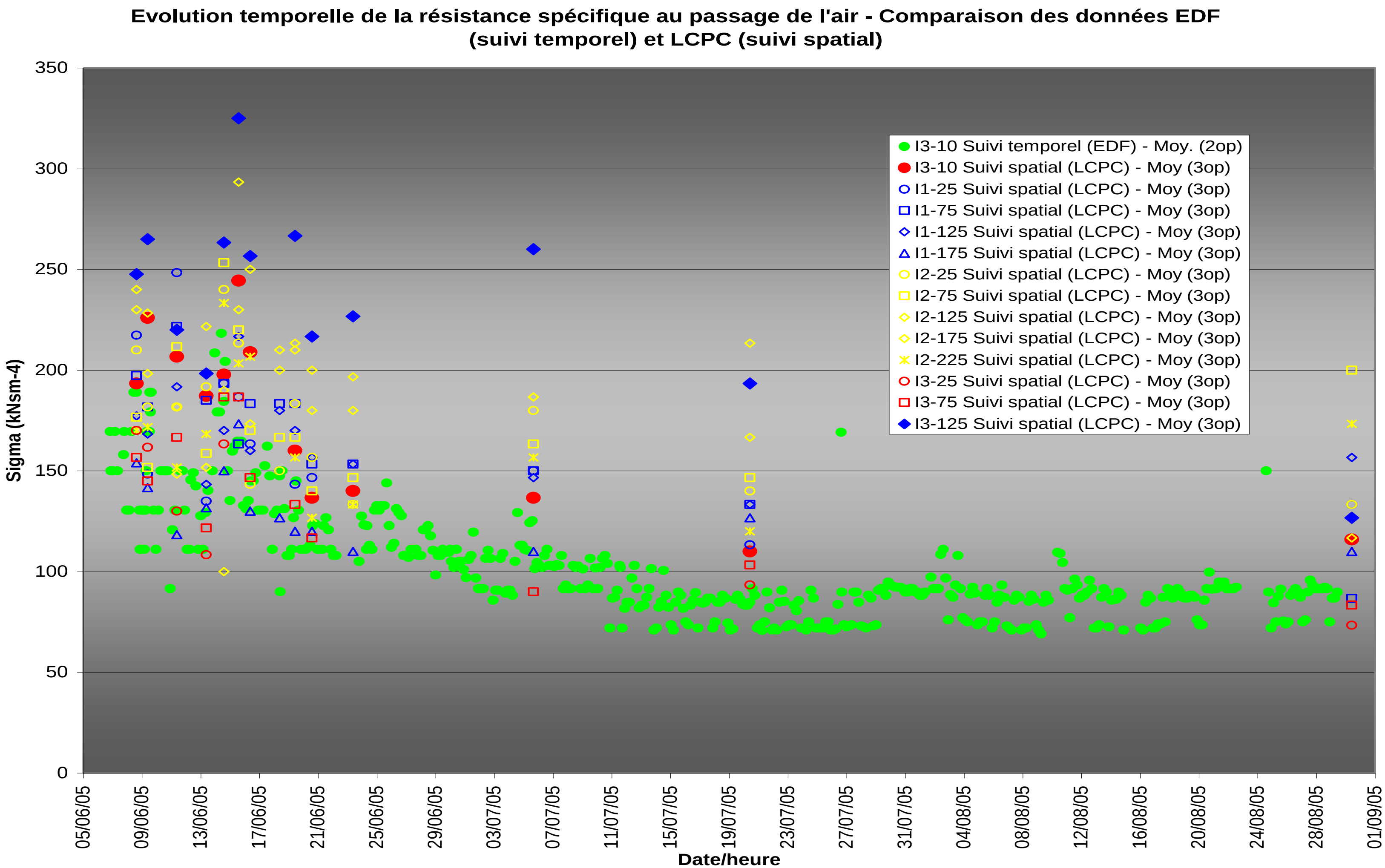
- Experimental results: ground impedance

- **Times series of air flow resistivity σ**



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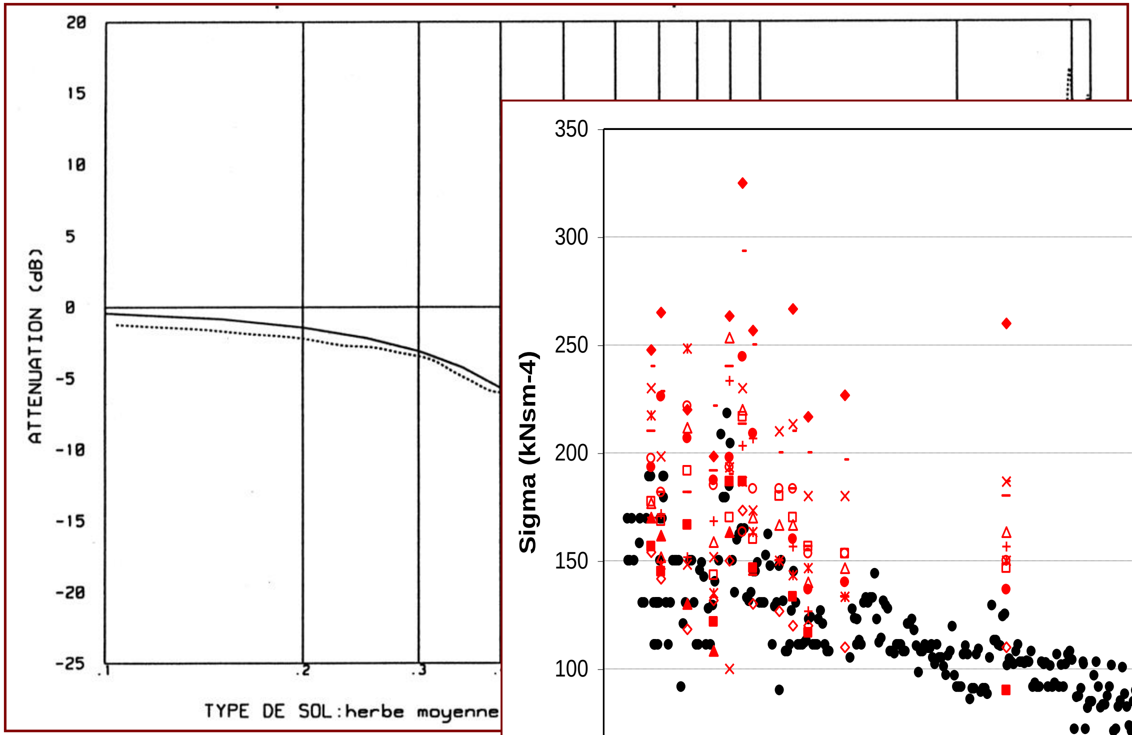
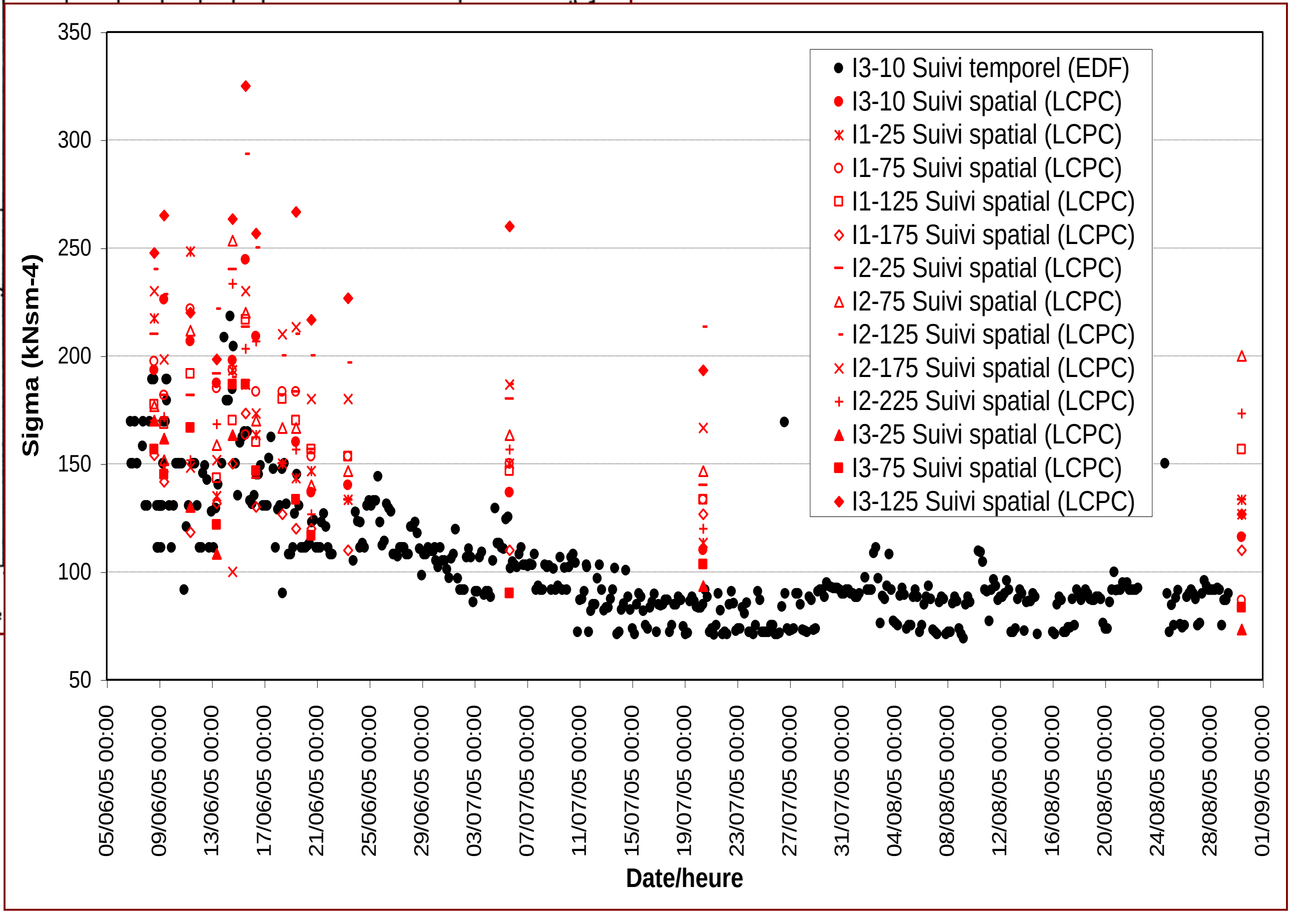
- **Impedance**
  - *Time AND space variability of air flow resistivity σ*





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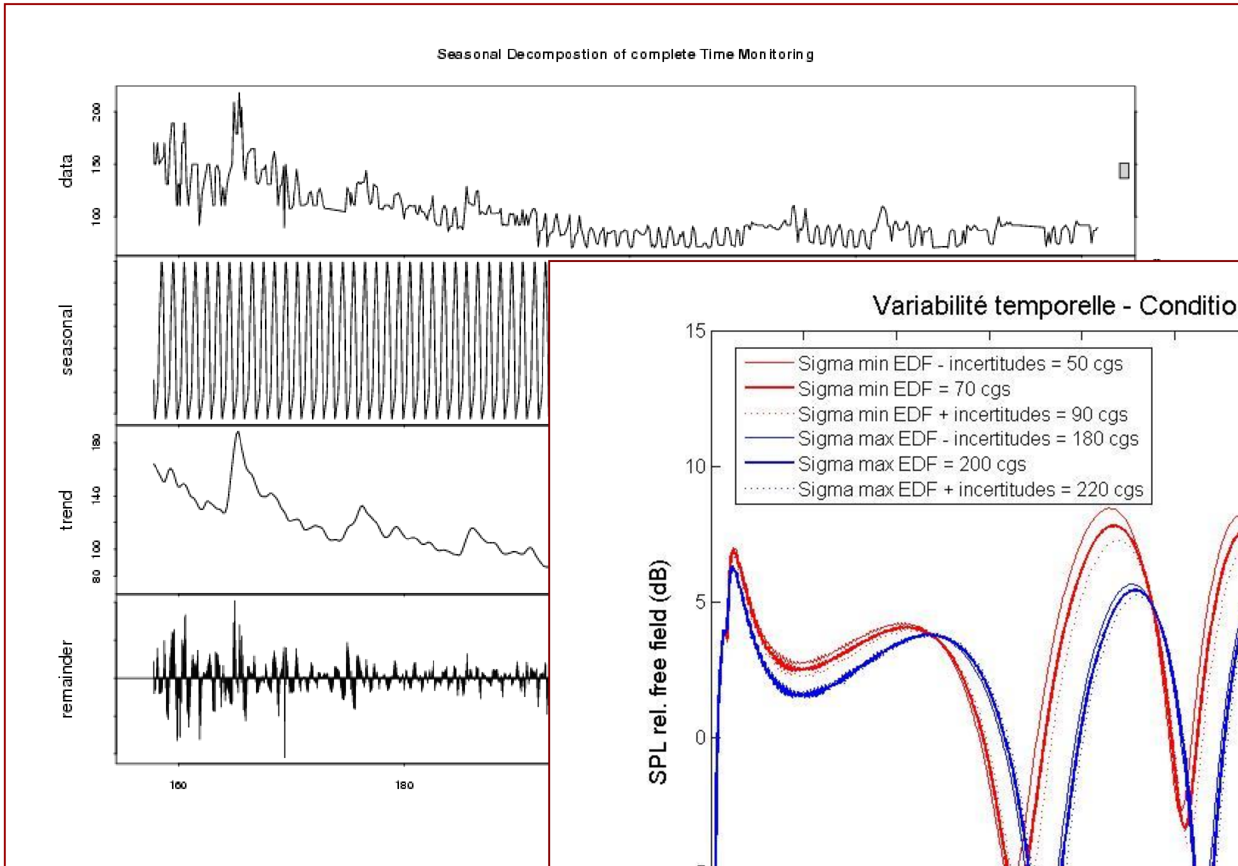
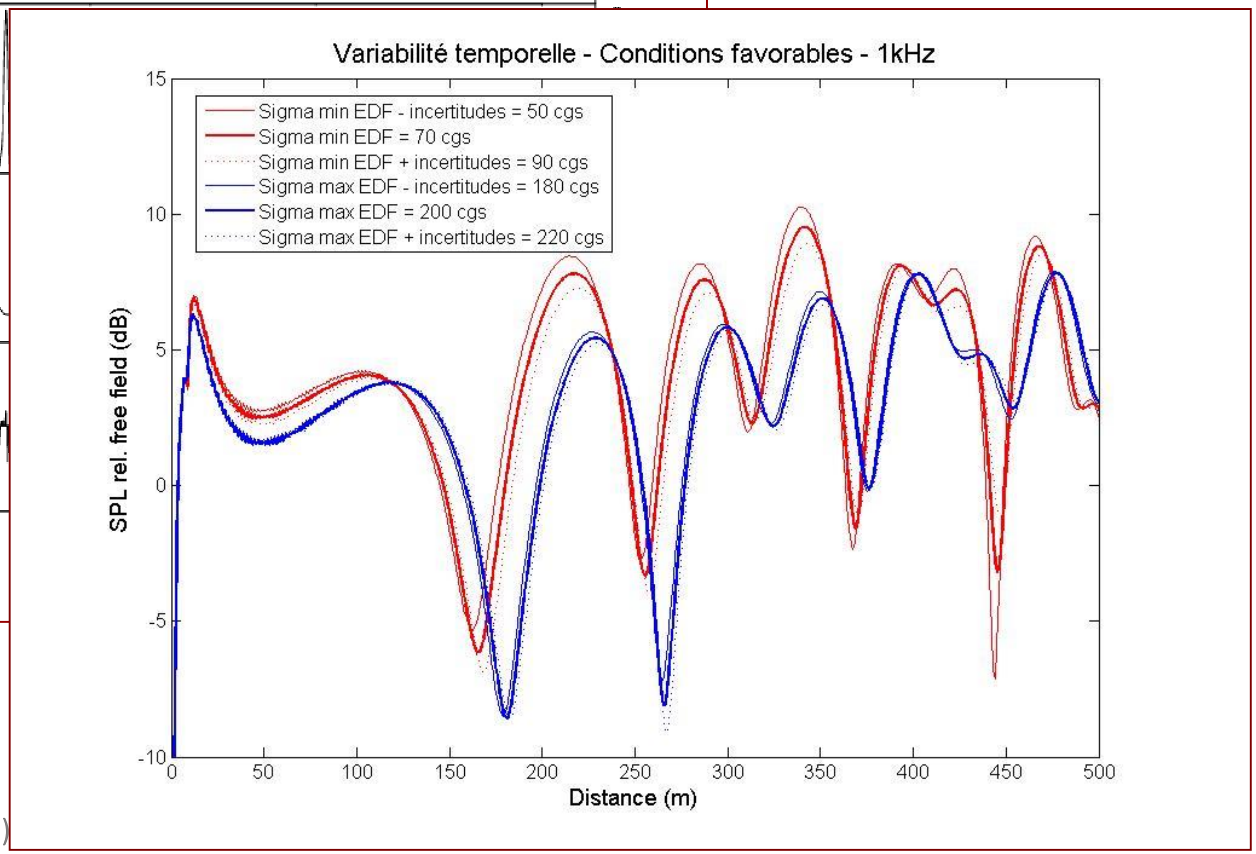
- **Time variability**





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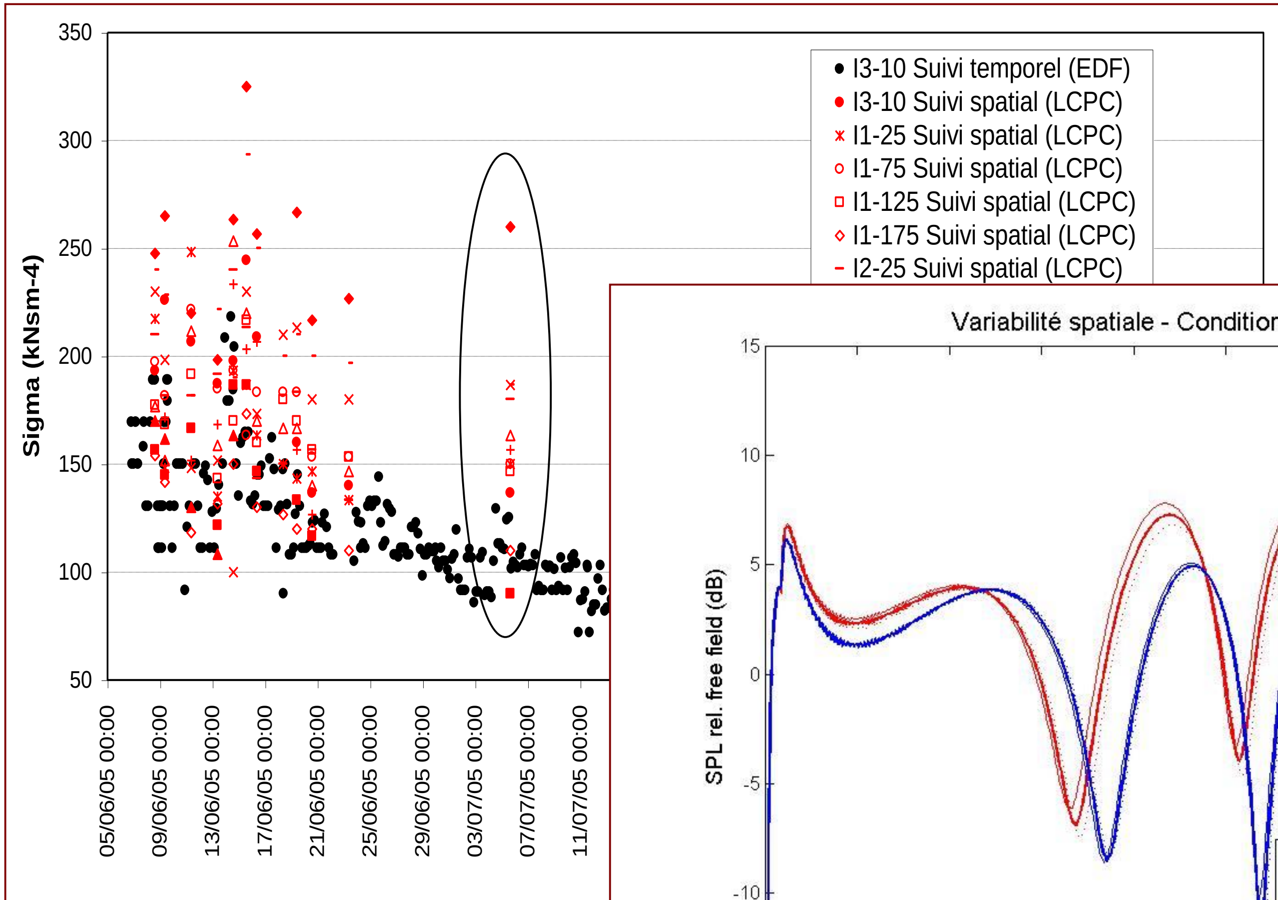
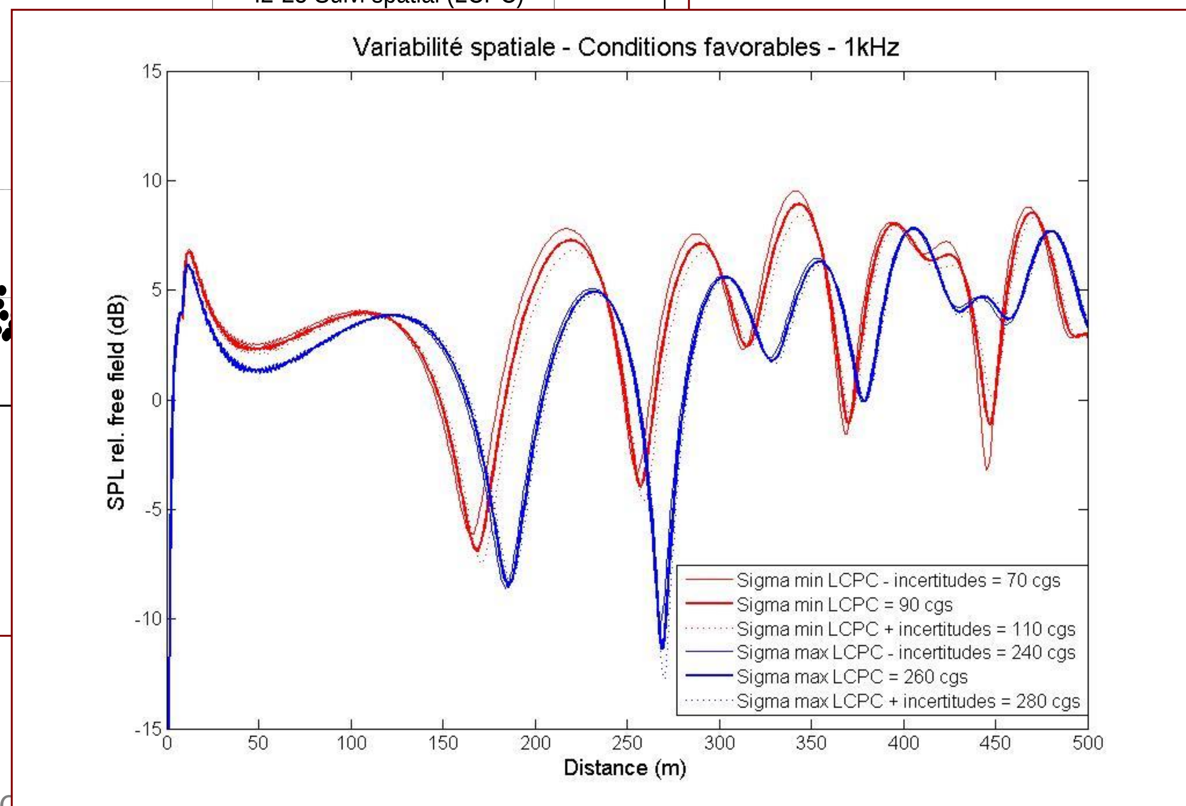
▪ Space variability





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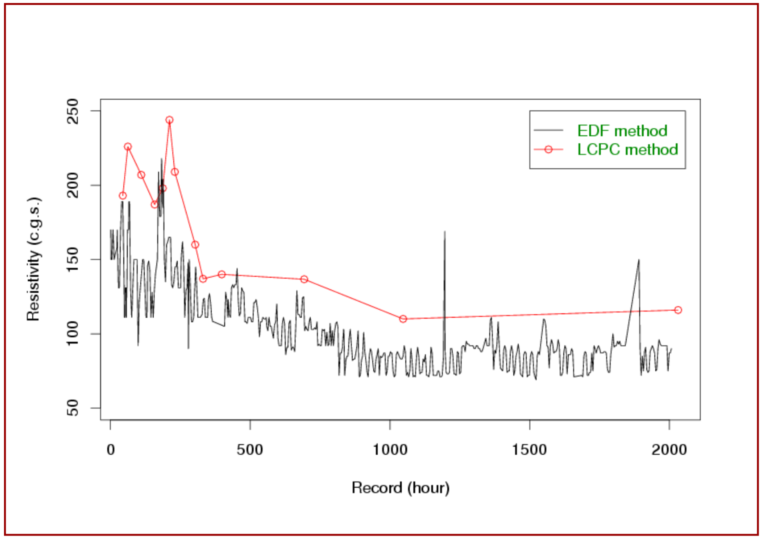
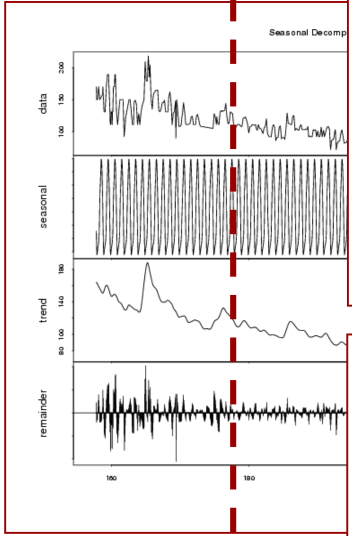
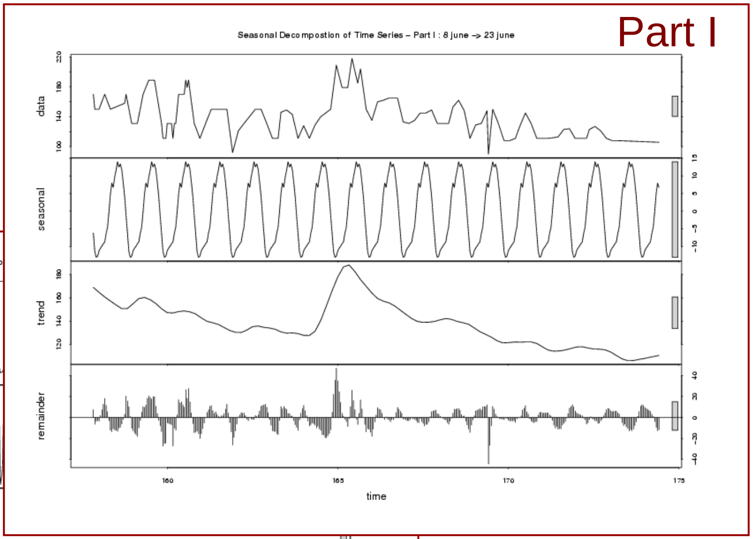
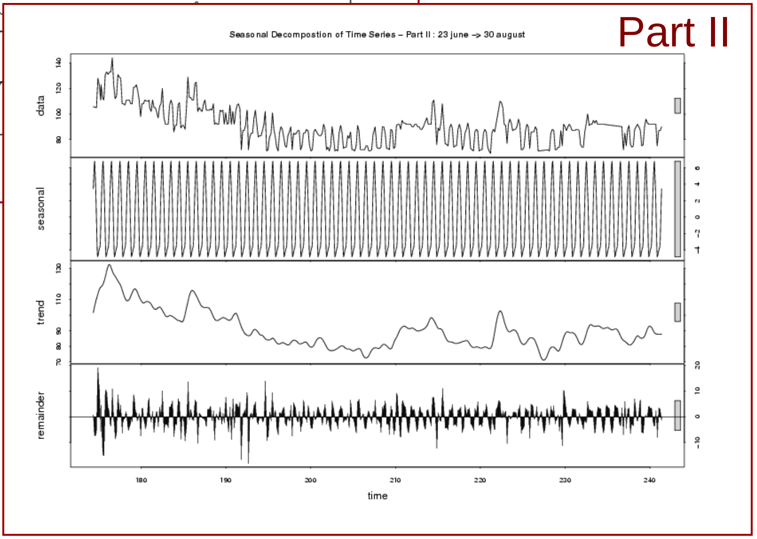
▪ Impedance

- ***Variabilité méthodologique*** **: Δσ ≈ 50cgs**
- ***Variabilité temporelle*** **: σ ≈ [70cgs;200cgs]**









- **Méthode de décomposition « STL »**
  - **Tendance générale (« trend »)**
  - **Périodicité journalière (« seasonal »)**
  - **« *Incertitudes* » expérimentales (« remainder ») Δσ ≈ ±20cgs**
  - **Part I & Part II**

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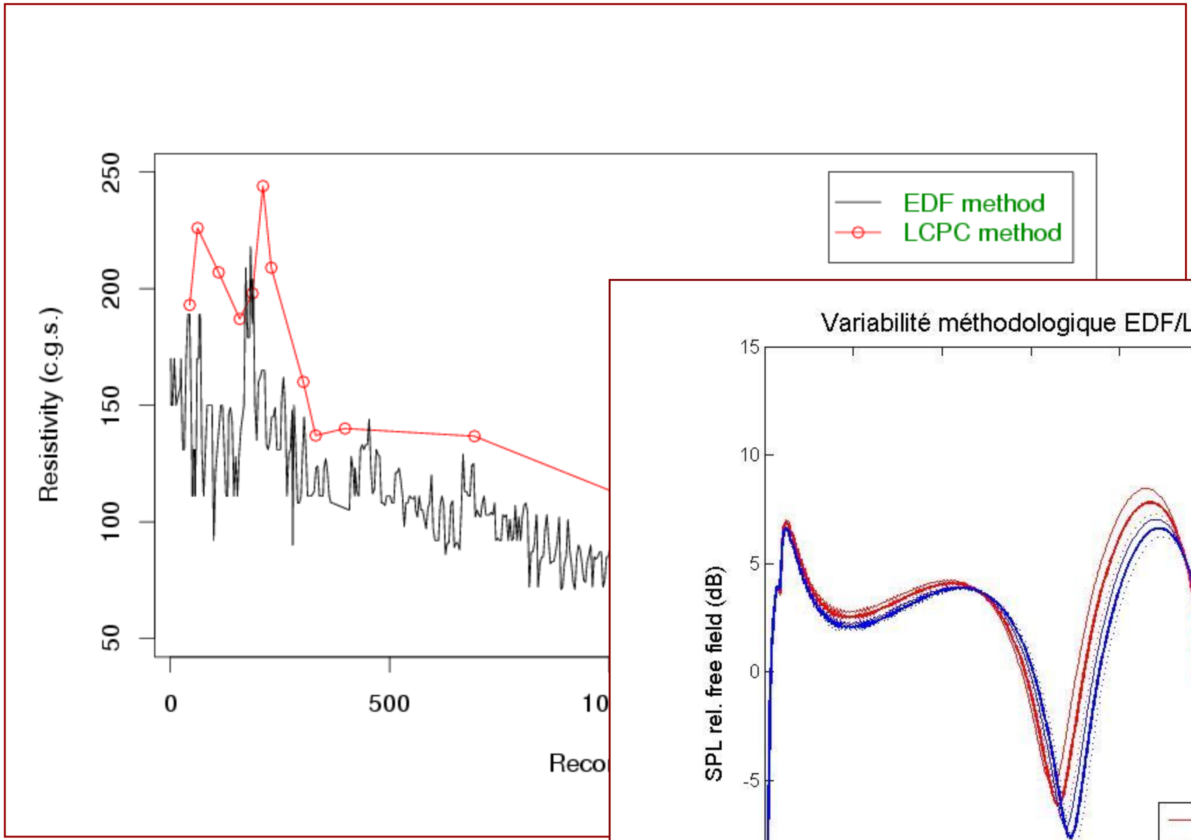
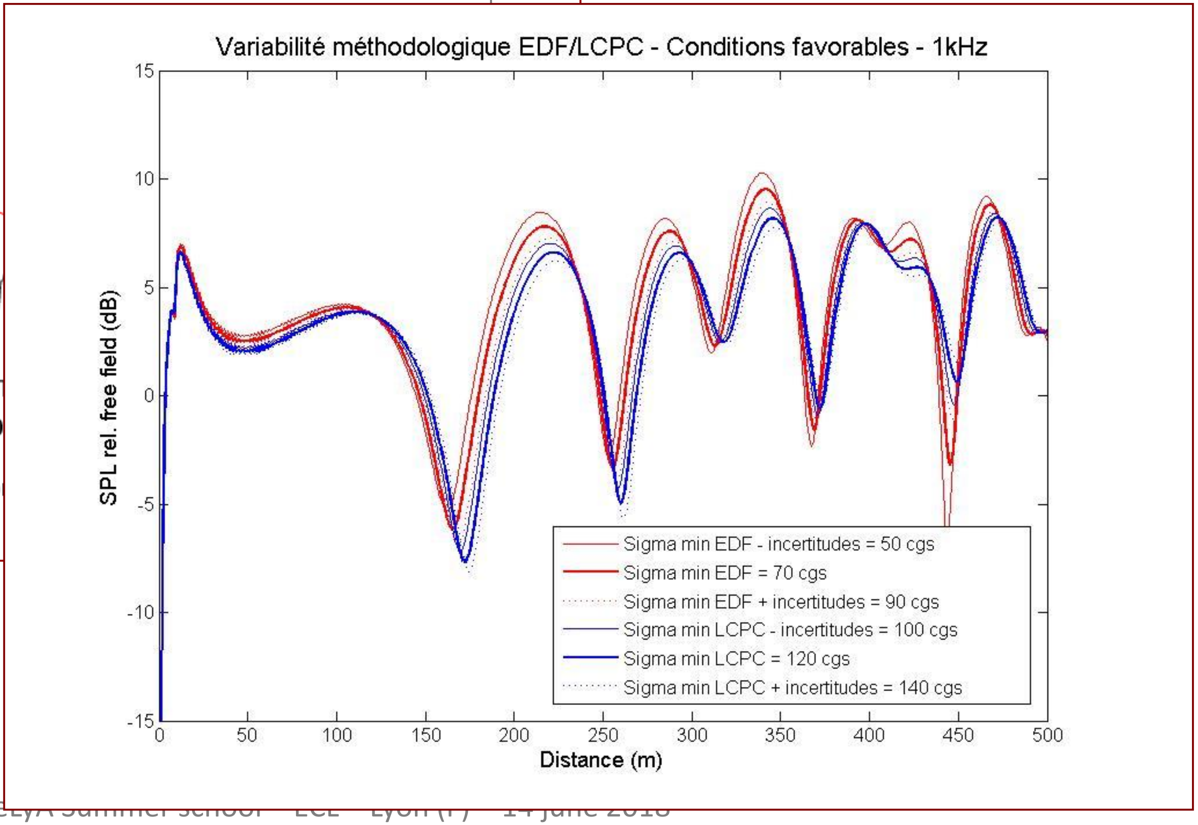
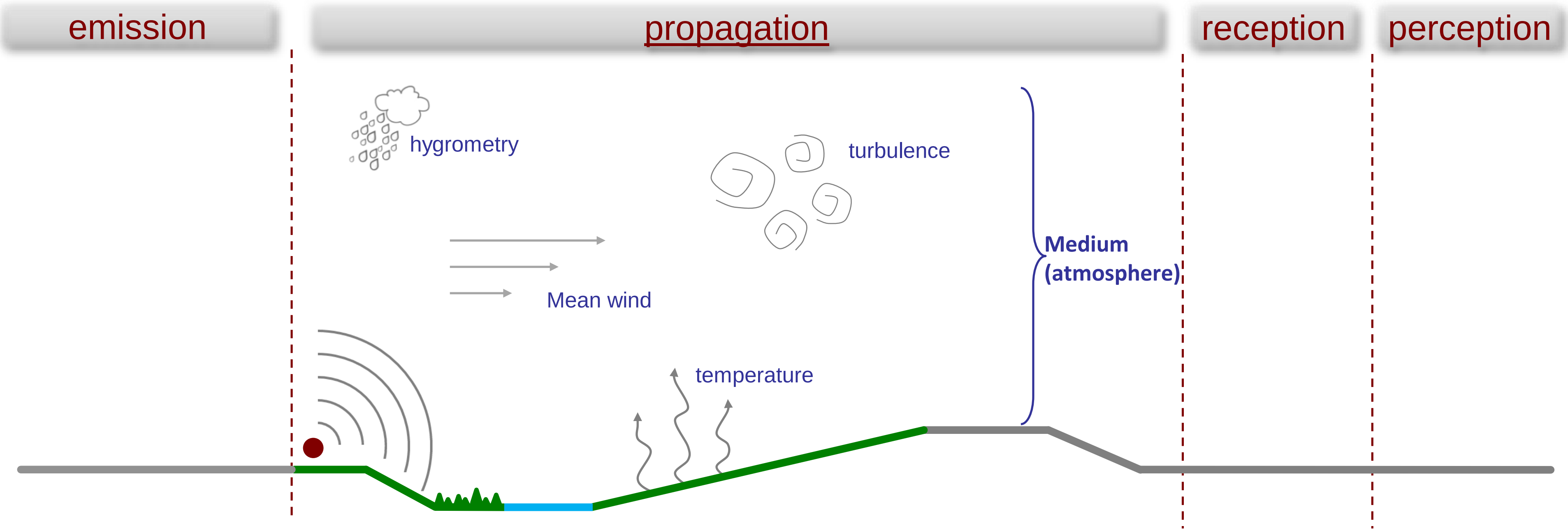
- **Methodological variability**



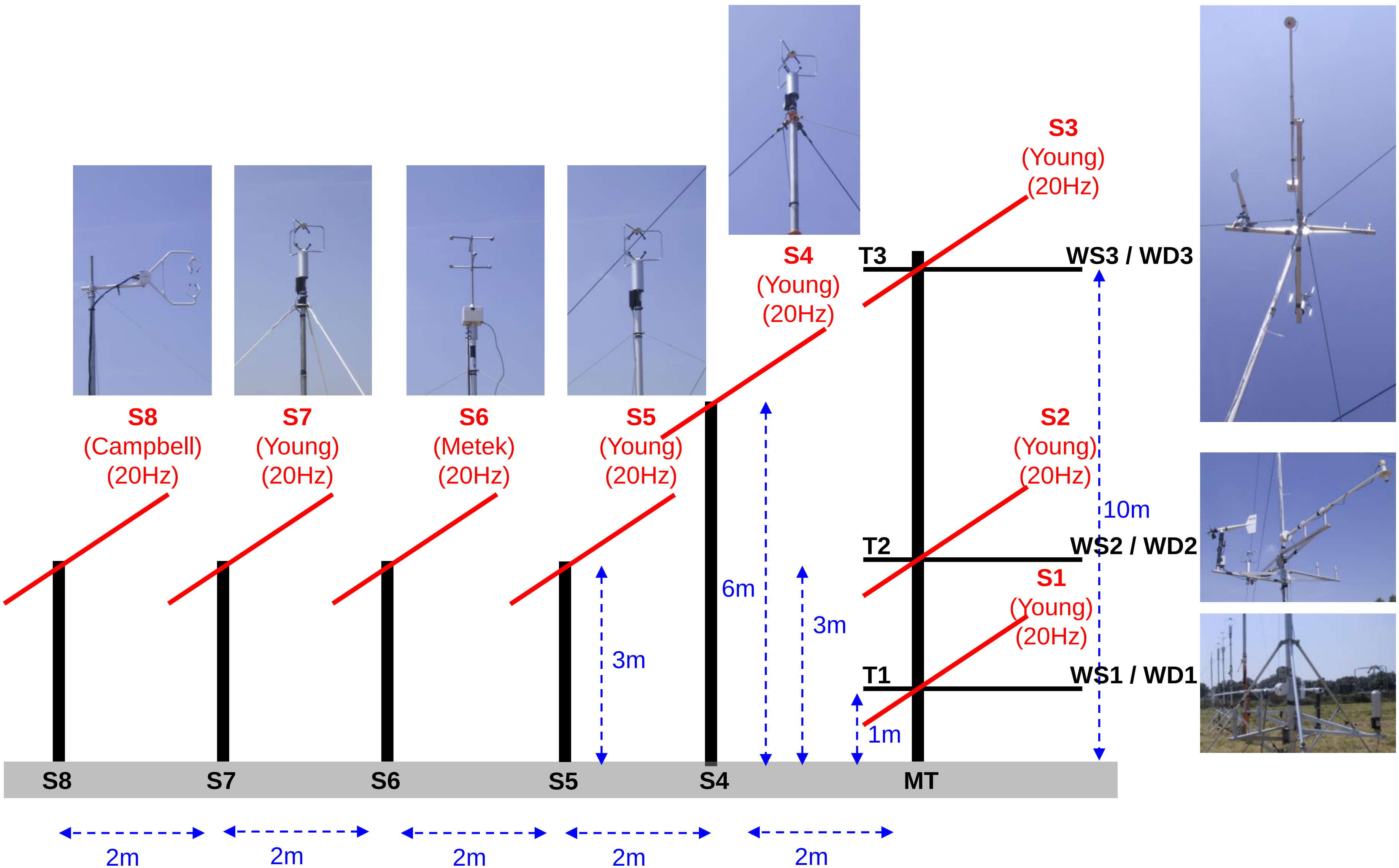


Sonic_2007



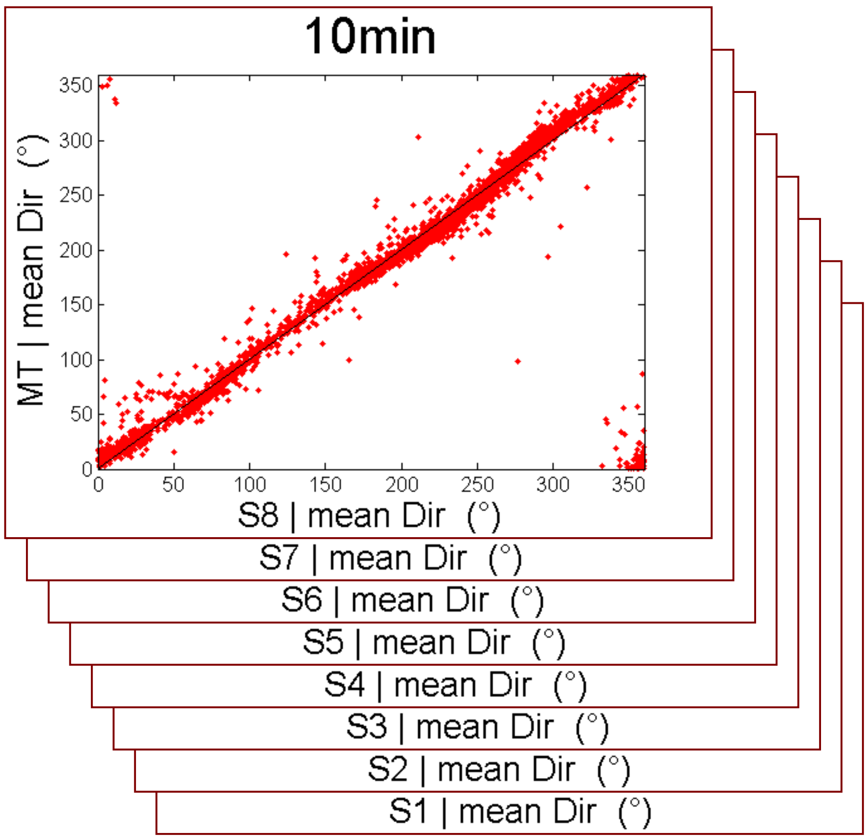
emission
propagation
reception
perception
hygrometry
turbulence
Mean wind
temperature
Medium
(atmosphere)

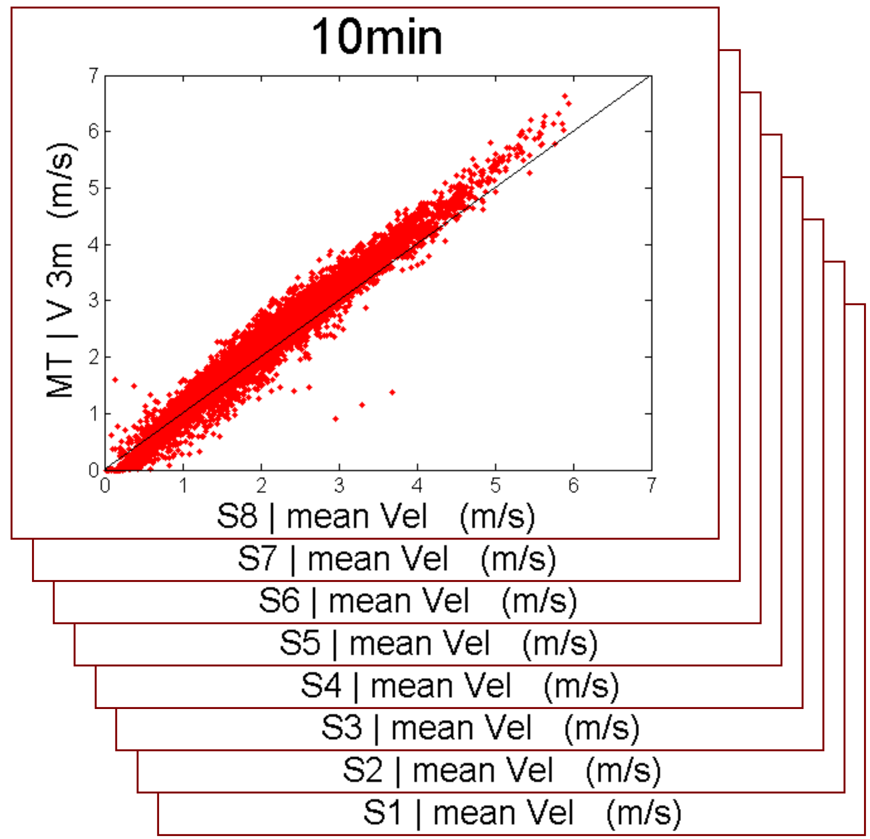
Experimental protocol



Validation process

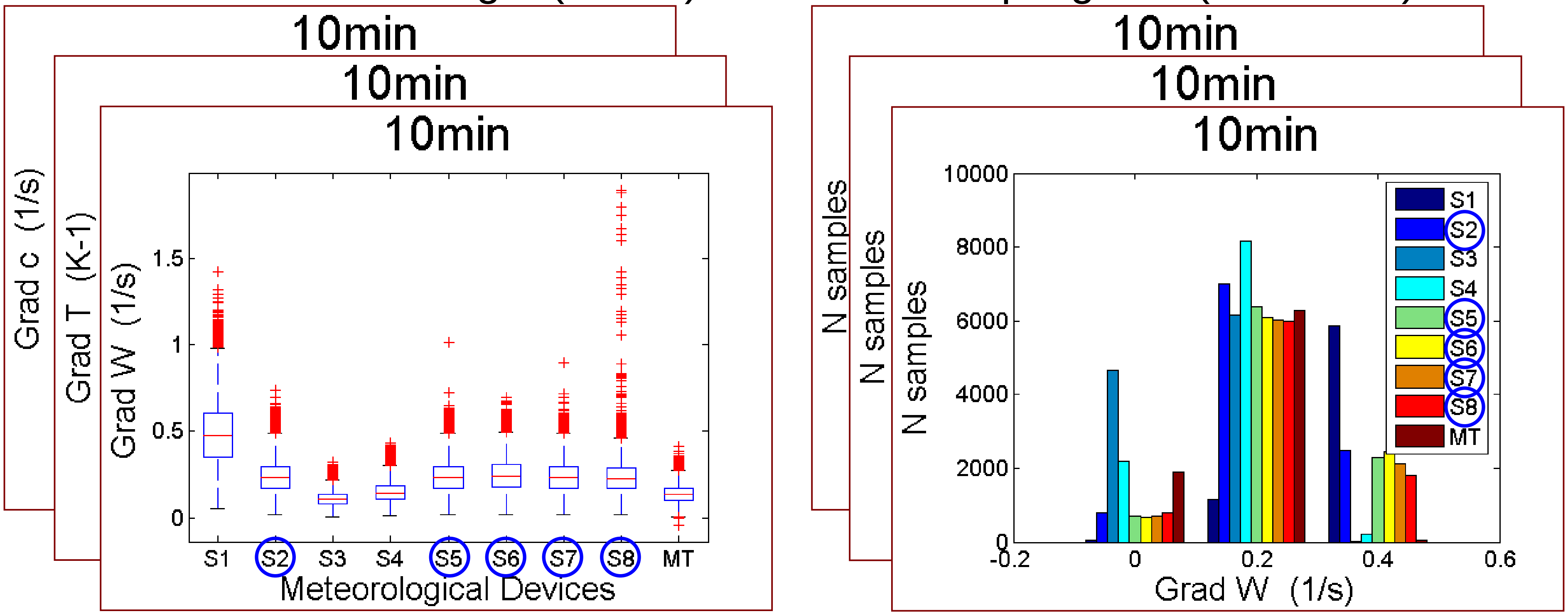
- Data post-processing
  - Erroneous values, e.g. $-2<z/L_{MO}<1$, $U^*>0.05ms^{-1}$, etc.
  - NAN values, e.g. rainy periods
-

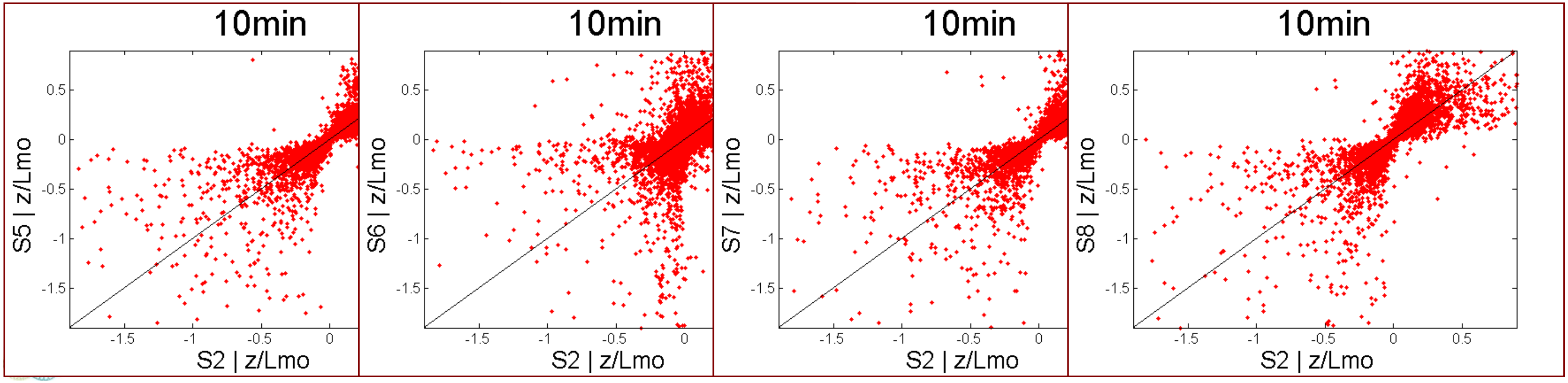




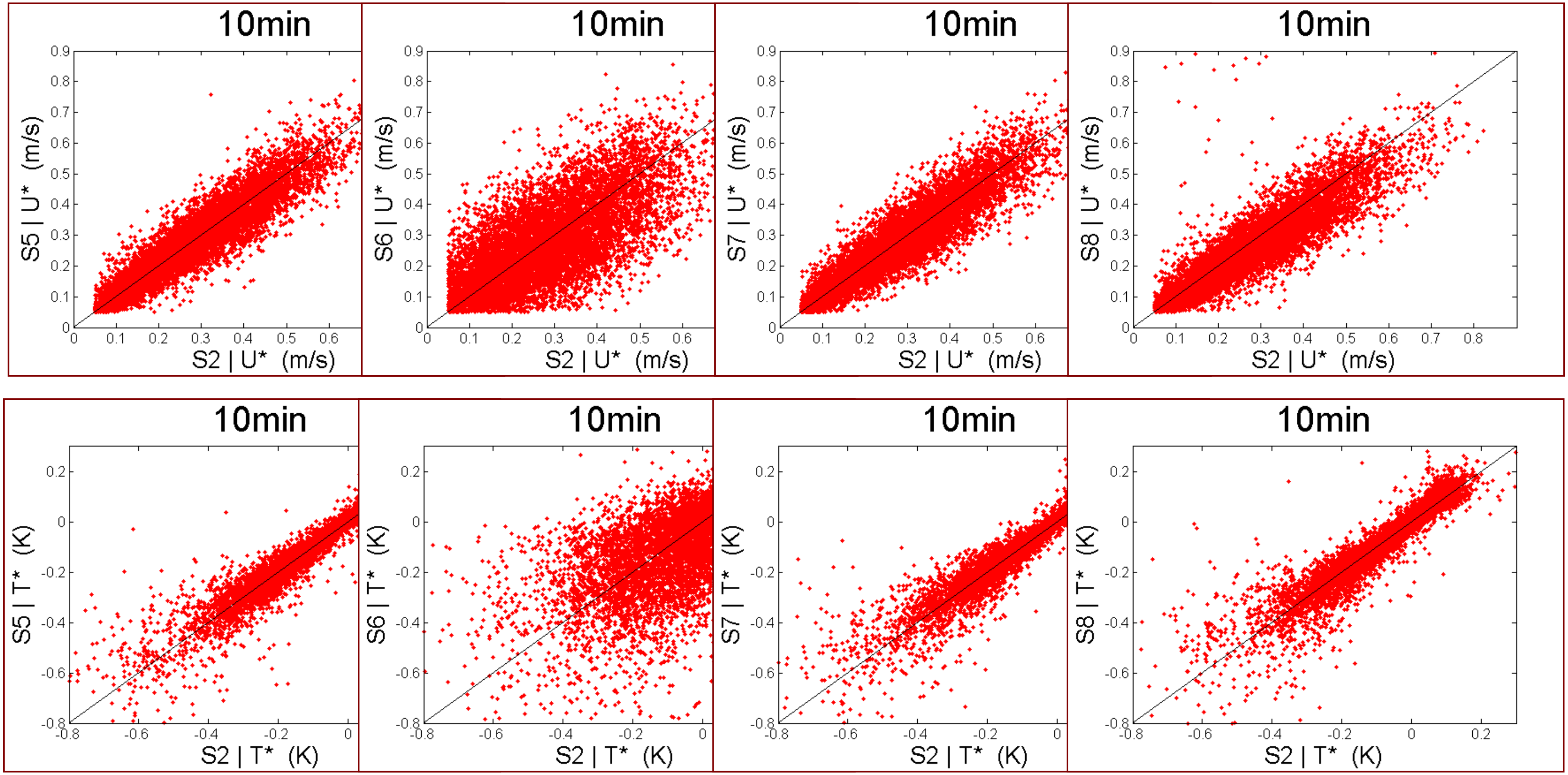
Sensitivity to devices (1/2)

Same sonics height (H=3m) and same sampling rate (SR=20Hz)





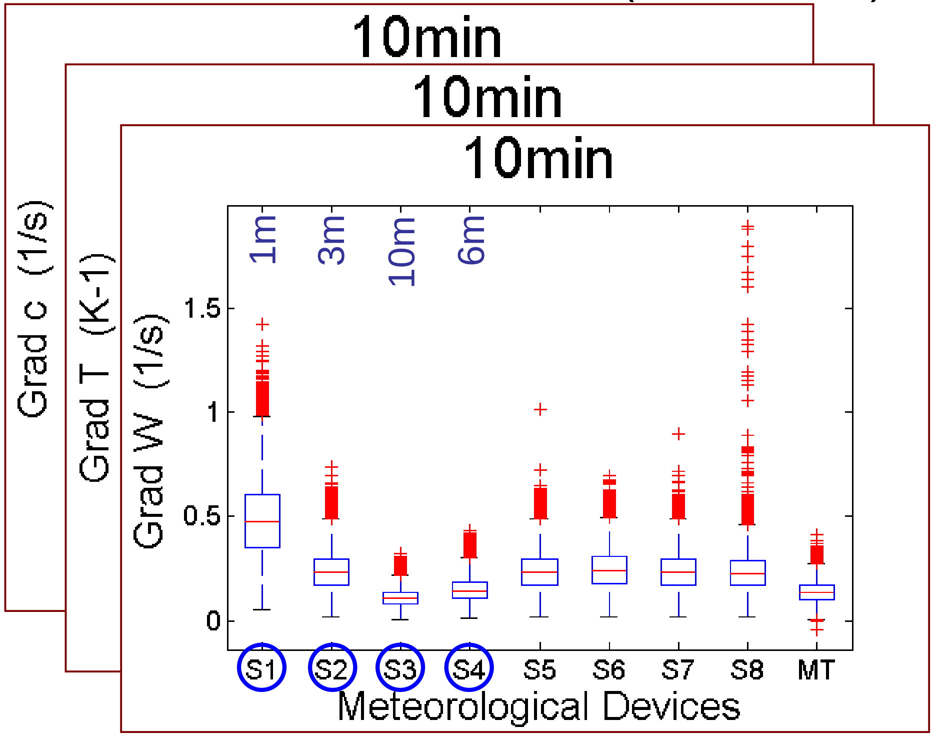
Sensitivity to devices (2/2)

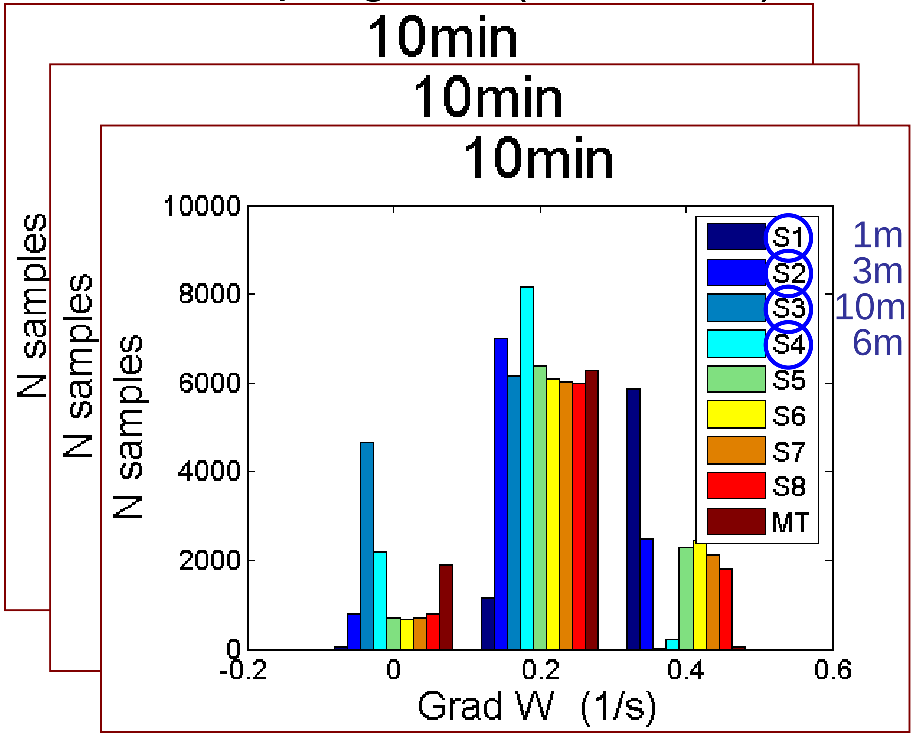


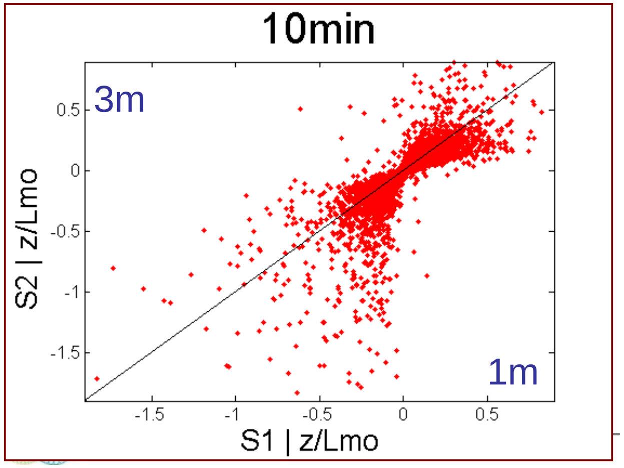
- Conclusions
  - Some discrepancies between sonics models (same height, same SR)
  - Mainly due to dispersion with U*, T*, z/L_{MO} and mean Dir (cosθ)
  - Ditto for 15min, 30min and 60min periods (same tendencies but less dispersion)

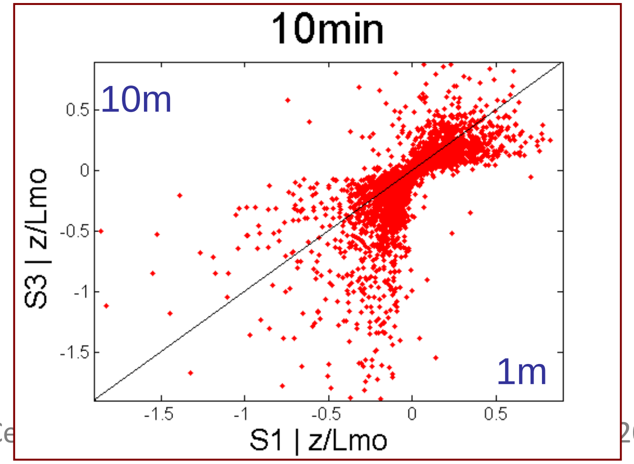
Sensitivity to meas. height (1/2)

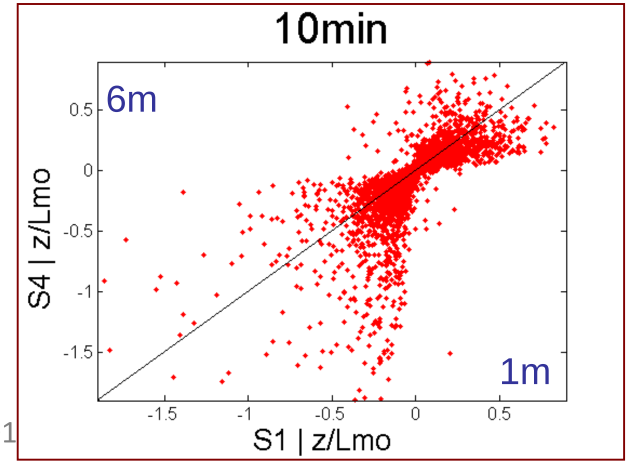
Same sonics model ("YOUNG") and same sampling rate (SR=20Hz)



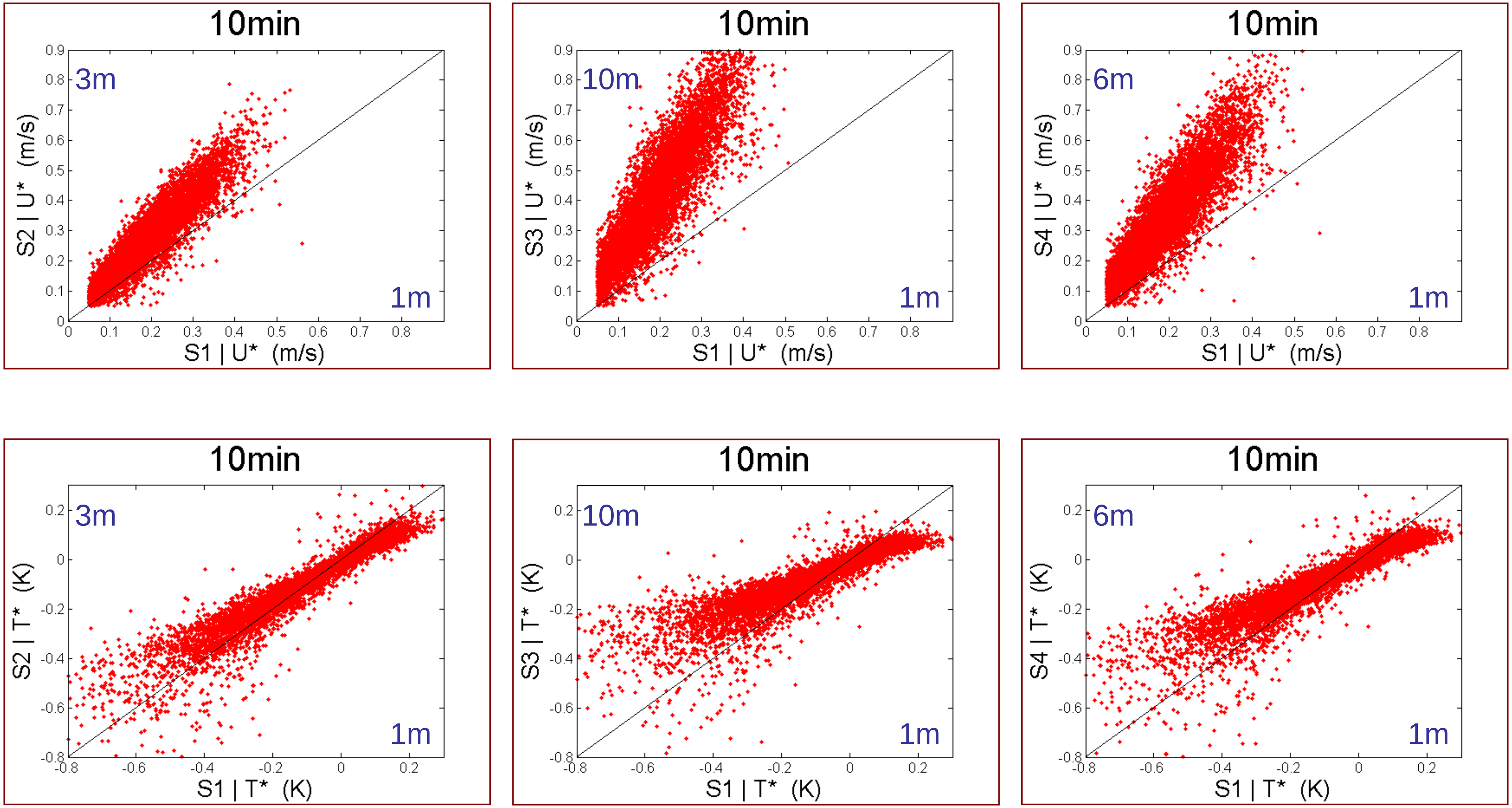






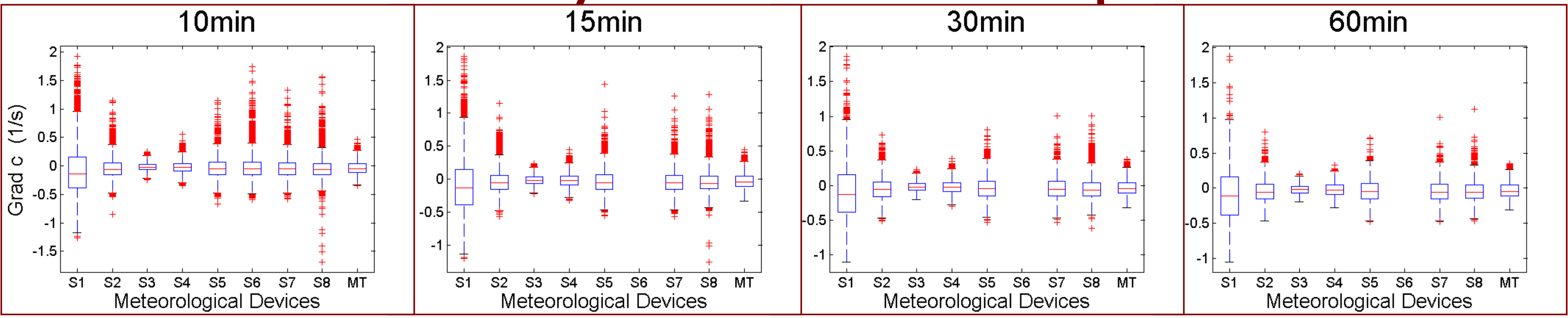


Sensitivity to meas. height (2/2)

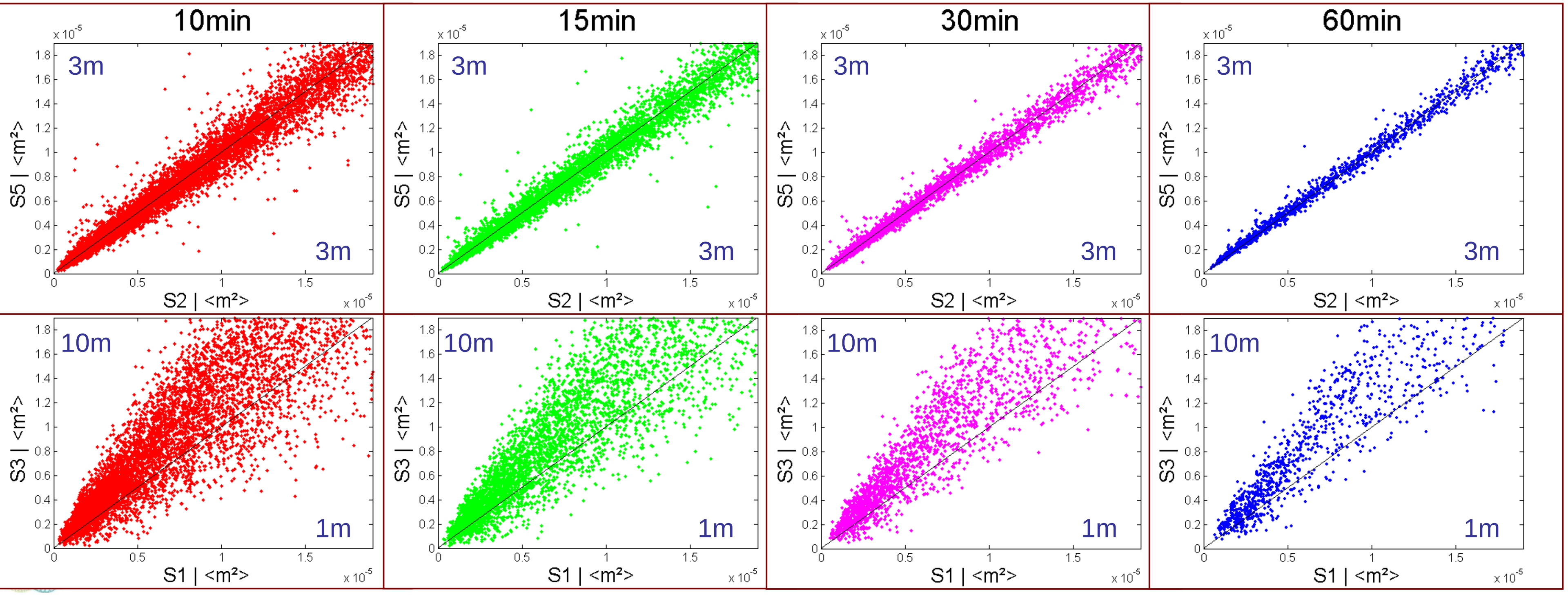


- Conclusions
  - Discrepancies between sonics heights (same models, same SR) : up to 0.6 s^{-1} for Grad_c
  - Mainly due to differences and dispersion in U* and T* (Cf univ. functions, with almost same z/L_{MO})
  - Ditto for 15min, 30min and 60min periods (same orientations but with less dispersion)

Sensitivity to meas. period



- Conclusions
  - Very slight discrepancies between measuring periods (mean values), but less dispersion with increasing period (and of course with increasing meas. height and increasing atmosphere stability)
  - Those conclusions are valid for mean refraction (*Grad_c*) but not always for atmospheric turbulence ($\langle \mu^2 \rangle$)



in-situ
Metrological uncertainties

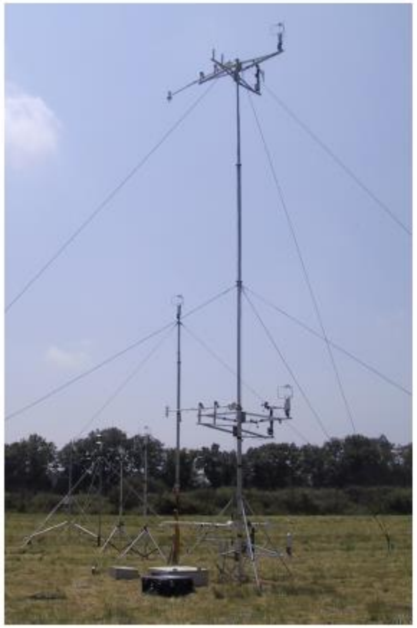


FIGURE: Mât équipé de capteurs météorologiques sur trois hauteurs (1, 3 et 10 m).

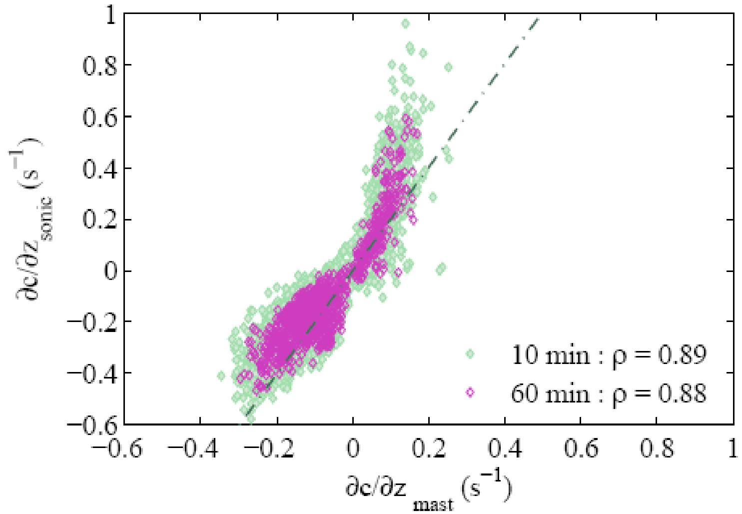
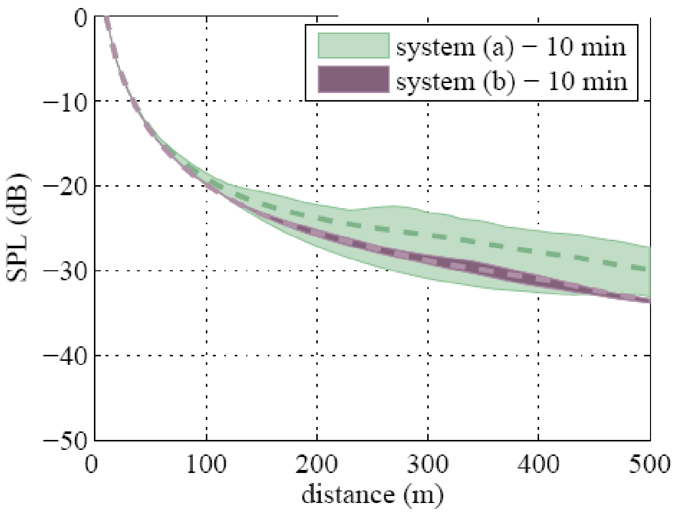
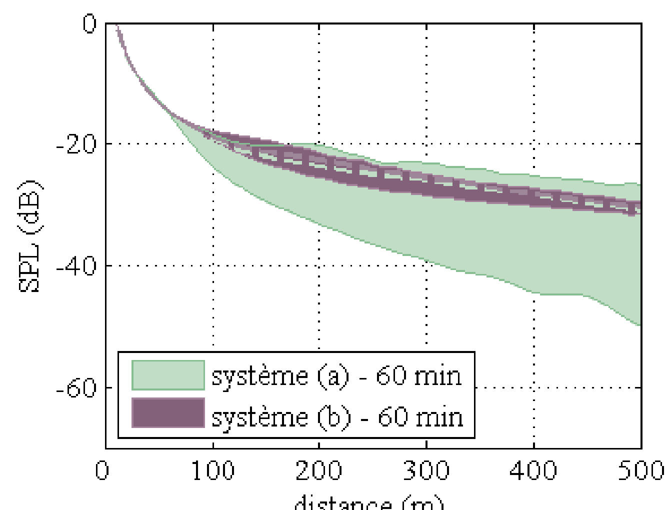
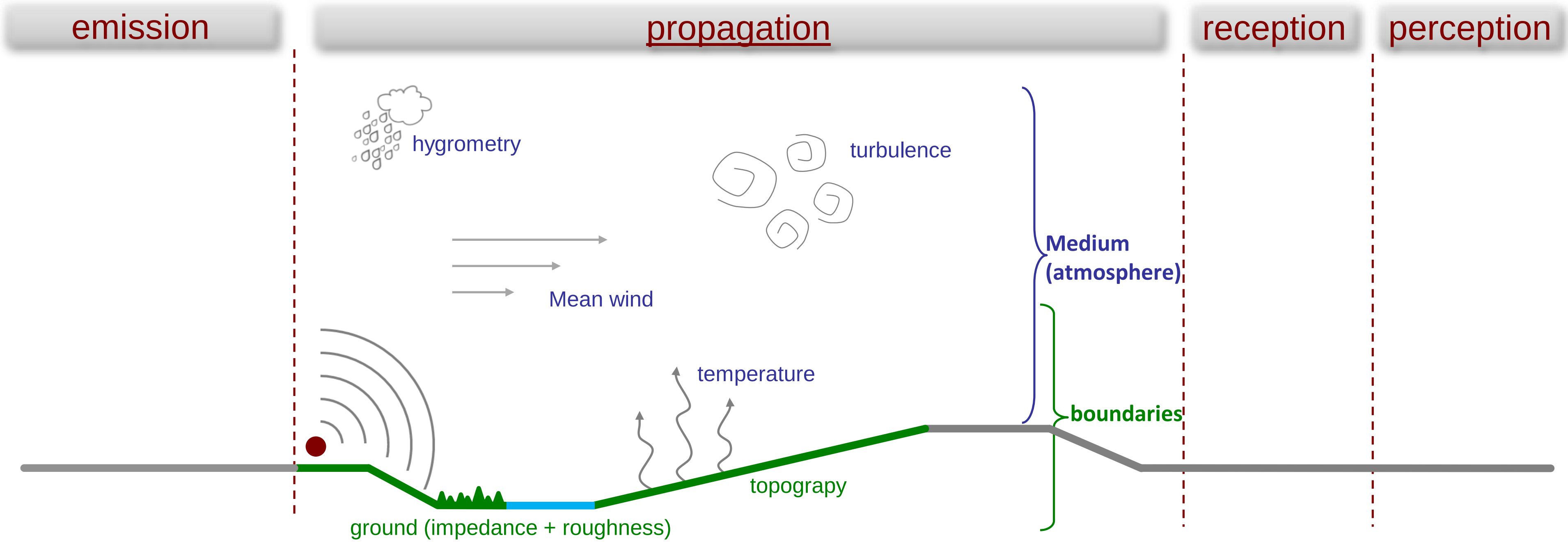


FIGURE: Anémomètre ultrasonique tridimensionnel.





LTMS_2002-2007



The Long Term Monitoring Station (LTMS, 2002-2014):

An experimental site for noise/traffic/meteo observation

A – Motivation

B – Presentation

C – Validation

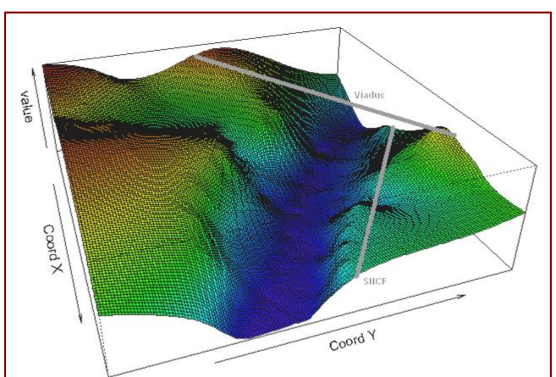
D – Application

- D.1 – Models validation
- D.2 – Statistical exploration

LTMS - Motivations

> Societal and scientific motivations

- Wide spreading of long range SPL due to fluctuations of influent parameters
  - (Emission: Sound source characteristics from road traffic)
  - Propagation:
    - Boundaries characteristics: Topography, obstacles, ground impedance, forests, *etc*.
    - Medium characteristics: Mean refraction and atmospheric turbulence (micrometeorology)
- Needs: Quantifying variability and uncertainty of SPL (cartography, impact study, *etc*.)
- Stakes: Estimating space and time representativeness of SPL
- Problematic: Representativeness of propagation conditions (ground and atmosphere)
  - Space representativeness >> Local effect ?
  - Time representativeness >> Long term ?



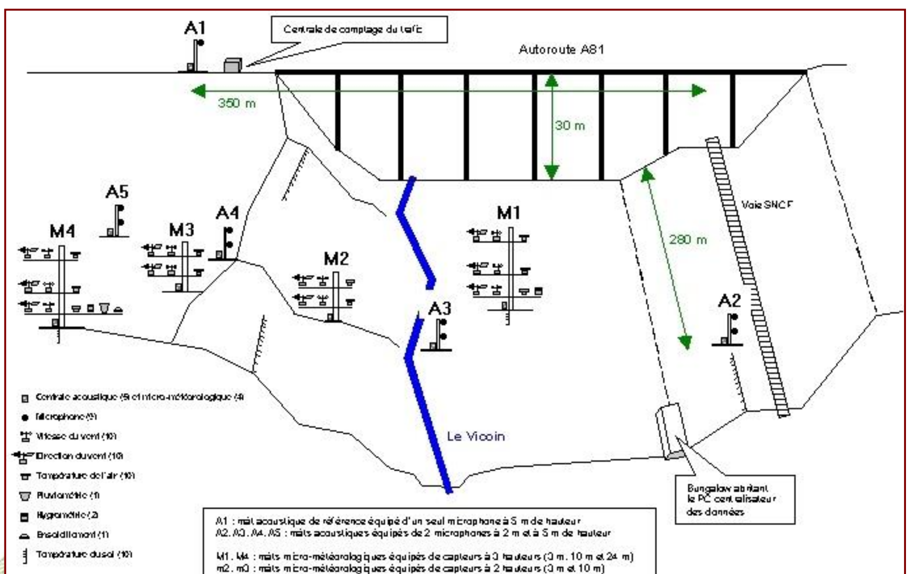
LTMS - Presentation

> LTMS and LTMS-2 (2007/2008, 319k€HT, 50% Région PdL)

- Financial support: IFSTTAR (ex-LCPC)
- Localization: Small valley at Saint-Berthevin (F, 53) – Sound sources: Road and railway traffic
- Data acquisition: 24h/24h (« monitoring ») since 2002, 10 seconds average samples
- 5 acoustical masts (2m and 5m measurement heights) – L_{eq10s} – Global (A) + 1/3 octave bands [100Hz;4kHz]
- 4 meteo towers (3m, 10m and 25m measurement heights) – Wind speed and direction, ventilated air temperature
- 4 ultrasonic 3D anemometers (on M1and M4, 3m and 10m measurements heights) + cloud cover monitoring
- Impedance monitoring (M3/A4, every 4h) + soil water and temperature monitoring + various additional sensors
- Road traffic characteristics: Time, lane, silhouette and speed (for each vehicle pass-by)
- Data synchronization, concatenation and transfer *via* web site (CECP Angers) + validation/filtering (LRB)

1999……2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010…

R&D | Run | LTMS | LTMS-2

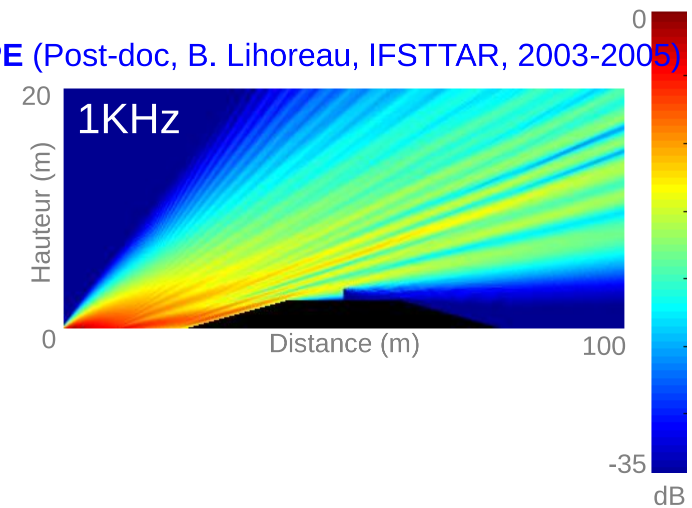


LTMS – Applications *(1)*

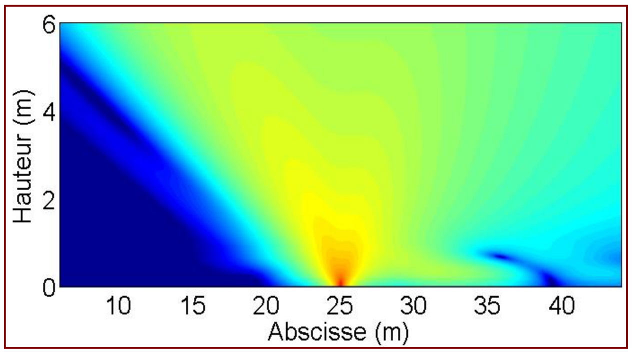
> Application 1: Numerical models validation + coupling

Propagation models

PE (Post-doc, B. Lihoreau, IFSTTAR, 2003-2005)



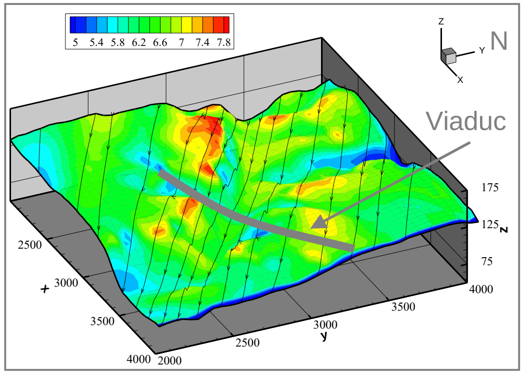
TLM (PhD Thesis, G. Guillaume, IFSTTAR, 2006-2009)



***Partnership:** RST, EC Lyon, CSTB, LAUM, EDF R&D, LRS, etc.*

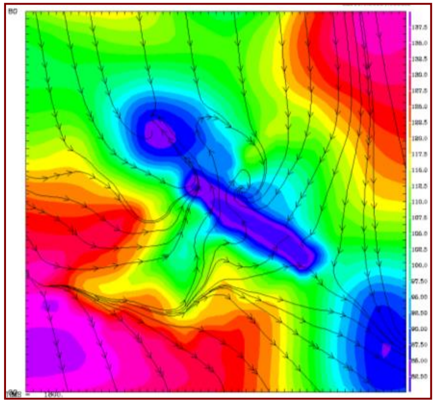
Micrometerological models

Submeso (PhD Thesis, T. Pénelon, EC Nantes, 1997-2000)



[Lihoreau et al., JASA 2006]

Méso-nH (PhD Thesis, P. Aumond, IFSTTAR/CNRM, 2008-2011)



2011

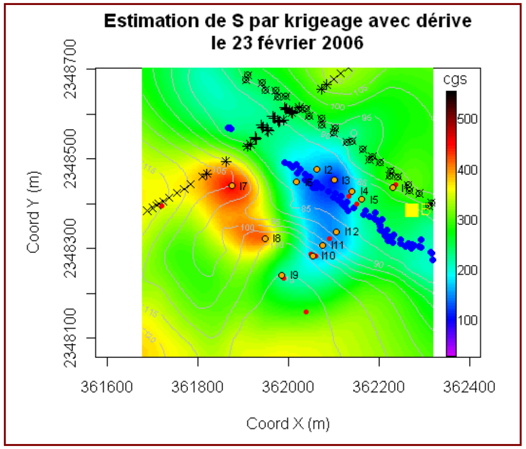
***Partnership:** EC Nantes, ISL, INRA, Météo-France (CNRM), etc.*

LTMS – Applications (2)

> Application 2: Statistical exploration

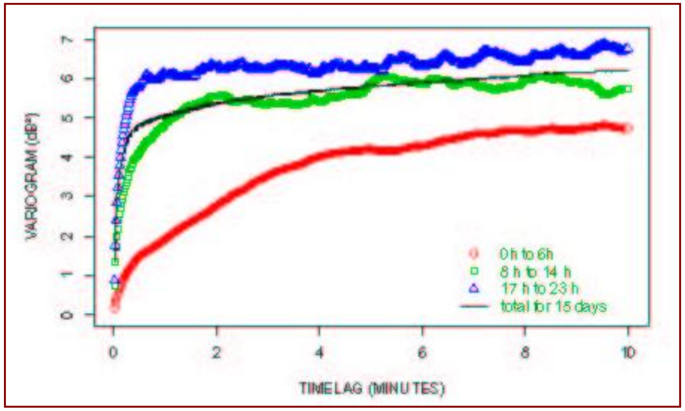
- Space and time representativeness
  - Short-term *vs* Long-term
  - Regional scale *vs* Local scale
  - Geostatistics
- Classification
  - Variability and uncertainty
  - Relative influence of ground/meteo parameters
  - Multidimensional analysis

Estimation of σ with kriging method [Bellanger, 2010]

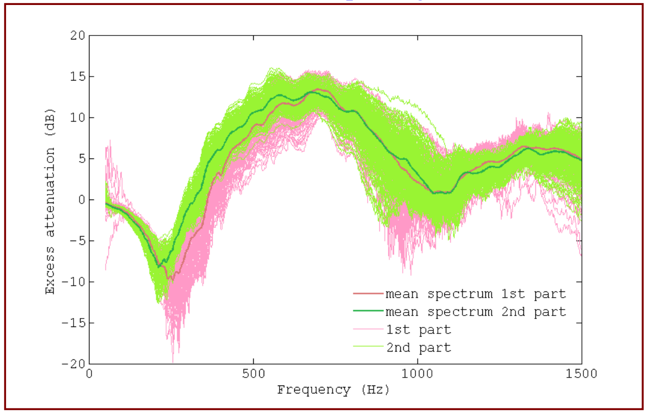


PhD Thesis (IFSTTAR/ EDF R&D):

Experimental variogram [Baume et al., JASA 2009]



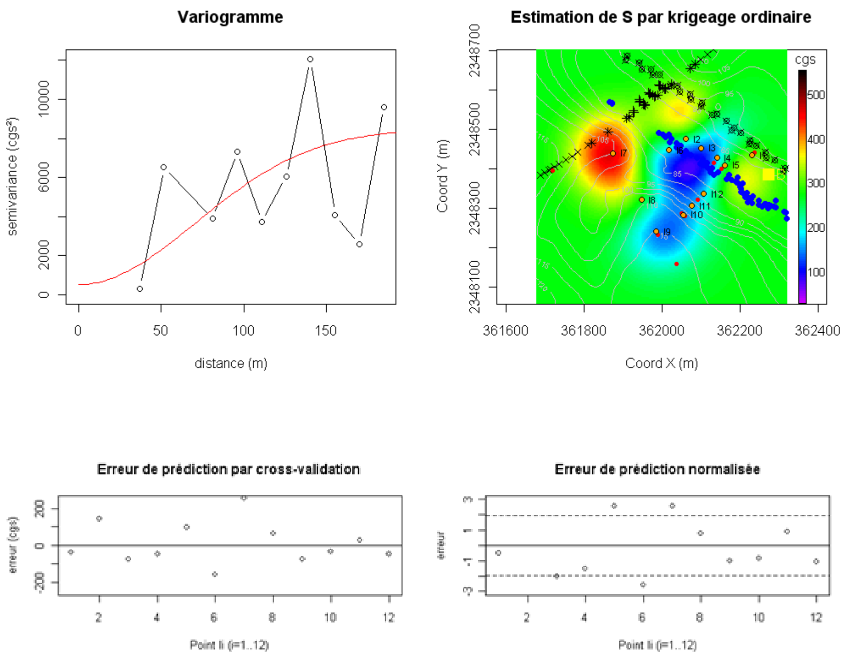
Calibration under uncertainties [Leroy et al., JASA 2010 ?]



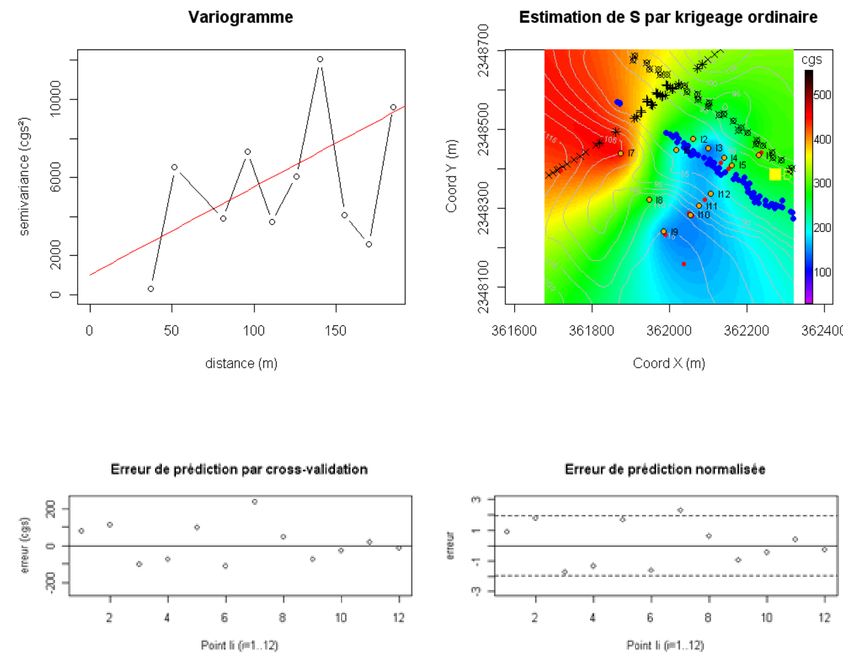
Partnership: *RST, EDF R&D, École des Mines de Paris (Centre de Géostatistique), etc.*

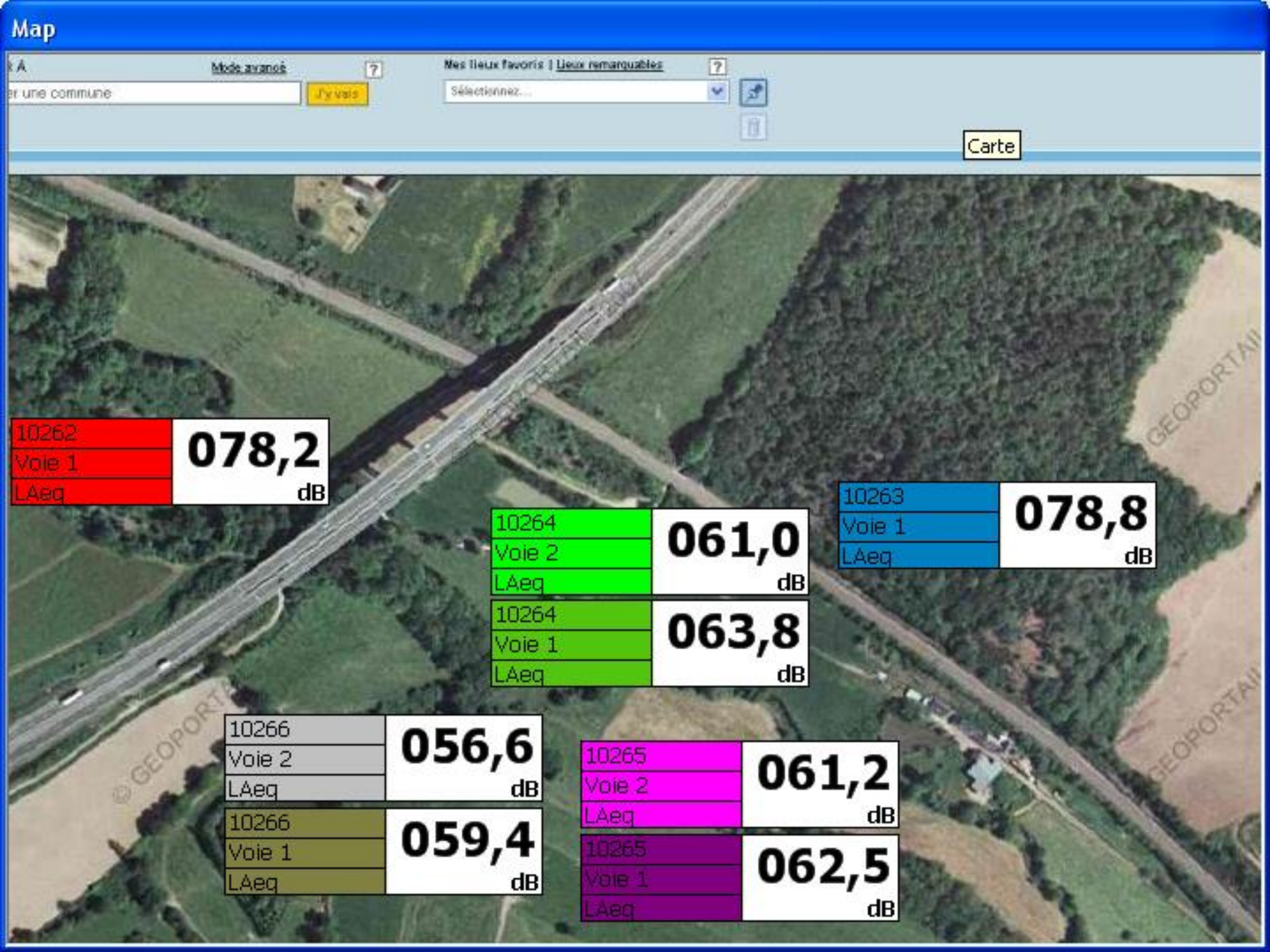
Variogram model

- **gaussian model:**



- **linear model:**




Map
Mode avancé
J'y vais
Mes lieux favoris | Lieux remarquables
Sélectionnez...
Carte
10262
Voie 1
LAeq
078,2
dB
10263
Voie 1
LAeq
078,8
dB
10264
Voie 2
LAeq
061,0
dB
10264
Voie 1
LAeq
063,8
dB
10266
Voie 2
LAeq
056,6
dB
10266
Voie 1
LAeq
059,4
dB
10265
Voie 2
LAeq
061,2
dB
10265
Voie 1
LAeq
062,5
dB
© GEOPORTAIL


dBM@p
v1.0.0.2
Numéro de série
Voie
IP
Type
???
Ref (A1M5)
Birds
Railway traffic

LTMS – Validation (2)

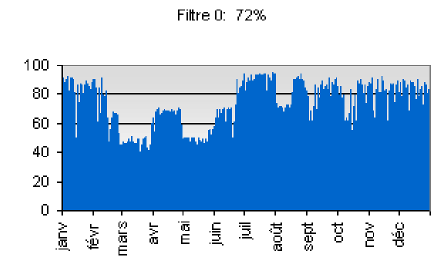
> Acoustical filters

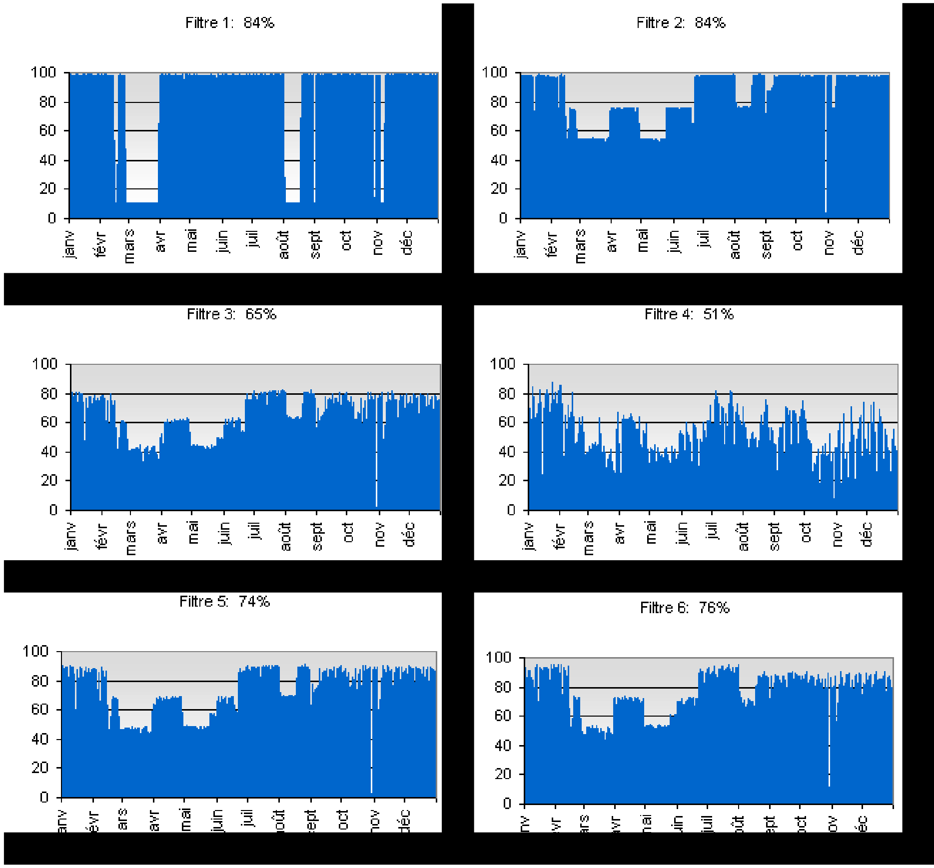
- Statistical and metrological methods
  - O. Leroy (M2)+ LRPC Blois
  - Criteria, threshold, *etc.*

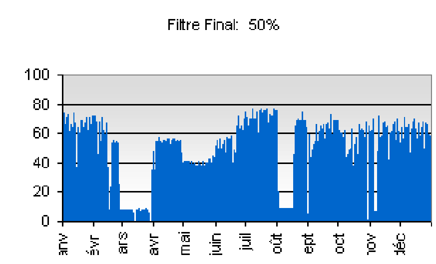
- 7 different and complementary filters
  - $$Final\ Filter = \sum_{i=0}^{6} F_i$$

- Acoustical assessment:

Year	|| Gentle	| Mid	| Strict
2002	|| 45 %	34 %	23 %
2003	|| 54 %	48 %	29 %
2004	|| 68 %	59 %	35 %
2005	|| 59 %	50 %	29 %
2006	|| 66%	56 %	31 %
2007	|| 34 %	29 %	16 %







LTMS – Available data

Raw database (45Mo/day),
# of 10sec samples (2002-2007):
337 630 475 / year = 2 025 782 850

Validation

Validated dabase (2002-2007),
# of 10sec samples = 1 216 387 160

Composition

Validated dabase (2002-2007),
# of 15min samples = 11 399 406

Full lines

- Acoustic (∀ mast, ∀ height, ∀ octave) : 10 (!)
- Meteo (∀ tower, ∀ height, ∀ parameter) : 69 820
- Traffic (∀ parameter) : 127 347

Full lines # - Selection

- A3_2m *rel.* A1 (A1M5 & A3M2, ∀ octave) : 1 118
- A3_5m *rel.* A1 (A1M5 & A3M5, ∀ octave) : 1 293
- A5_2m *rel.* A1 (A1M5 & A5M2, ∀ octave) : 1 830
- A5_5m *rel.* A1 (A1M5 & A5M5, ∀ octave) : 1 614
- M1 (DV_10m, VV_i, TA_i, i=3,10,25m) : 99 265
- M4 (DV_10m, VV_i, TA_i, i=3,10,25m) : 143 144

Numerical models
PhD P. Aumond
LCPC / MF-CNRM
2008-2011

Full lines # - Selection – Acoustic/meteo combination

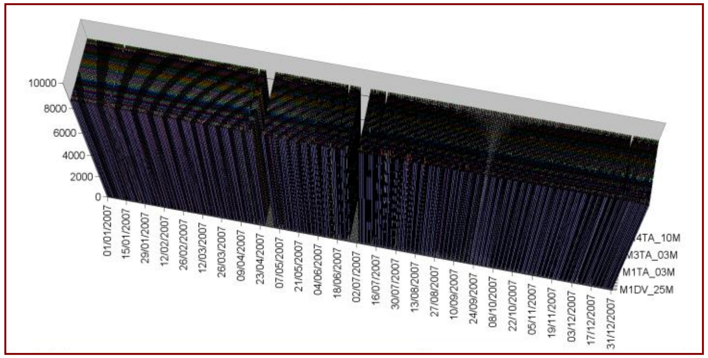
- A3M2 *rel.* A1 + M1 (valley / 2m) : 370
- A5M2 *rel.* A1 + M4 (plateau / 2m) : 1 496
- A3M5 *rel.* A1 + M1 (valley / 5m) : 420
- A5M5 *rel.* A1 + M4 (plateau / 5m) : 1 310

Statistical models
PhD O. Leroy
LCPC / EDF-R&D
2007-2010

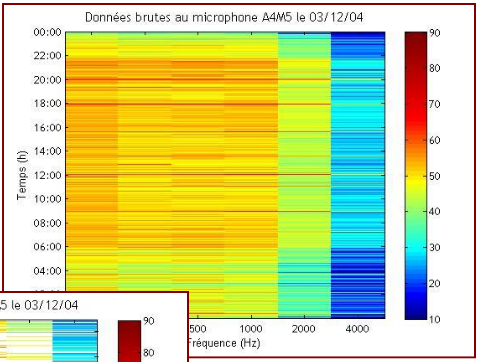
LTMS – Data validation

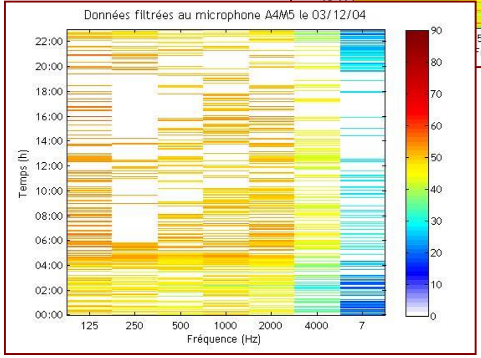
> Post-processing on LTMS databases

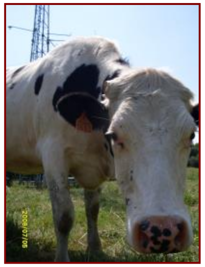
- Road Traffic
  - Raw database: 1 sample / vehicle (time, lane, silhouette and speed)
  - Post-processed database: 10sec assessment (N_VL, N_PL, V_VL, V_PL for each 4 lanes)
- Meteo conditions
  - Sensors dysfunctions
  - Transfer problems
  - Data validation/filtering
  - Example for 2007:



- $L_{eq15min}$
  - Metrological and/or transfer problems
  - S/N ratio
  - Parasitical sound events (animals, trains, *etc.*)
  - Data validation/filtering
  - Example for 2004/12/03:







LTMS – Data exploration

> Selection of period: 2002-2007 (6 years)

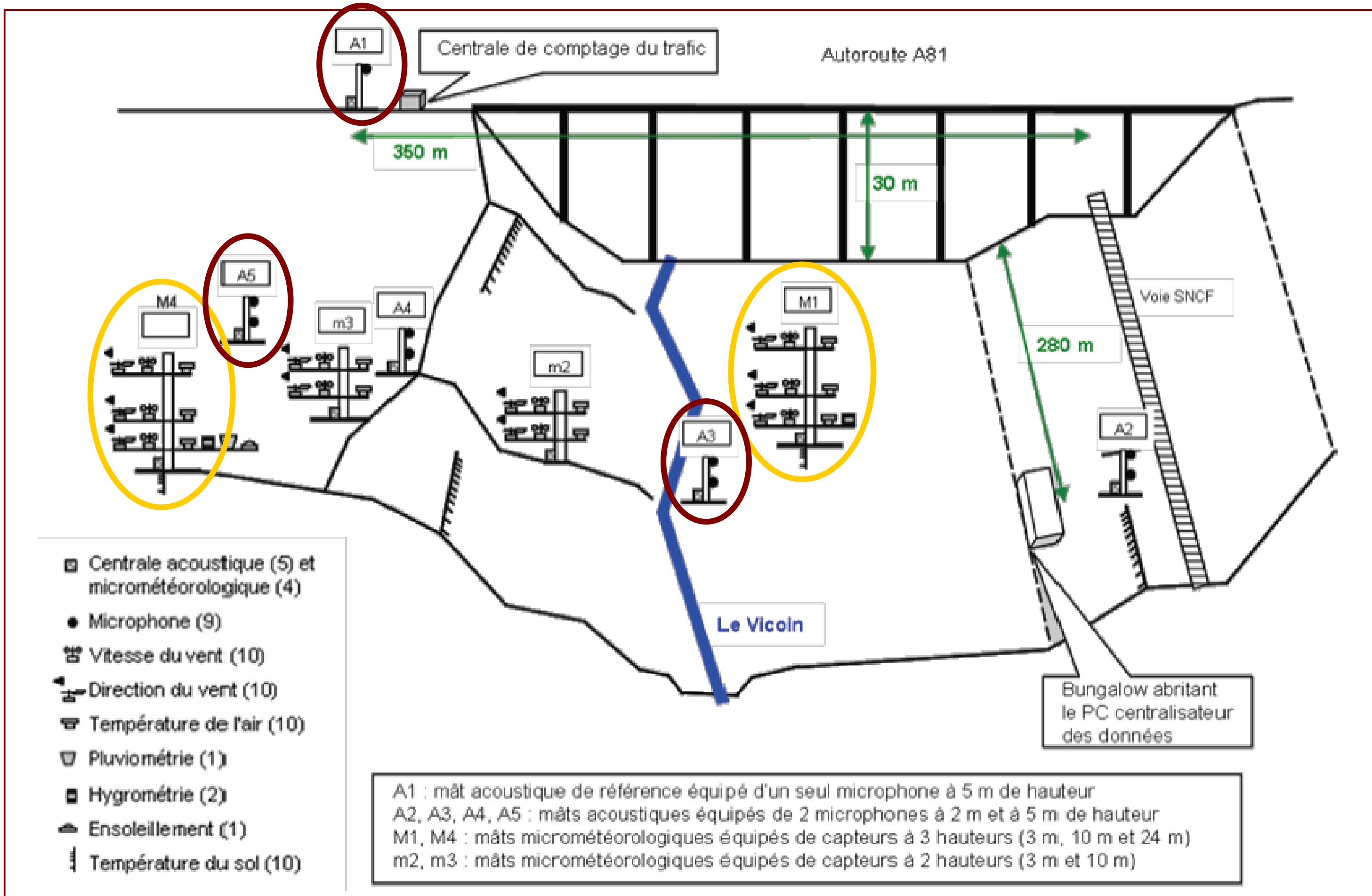
> Selection of variables:

Meteo:

- M1 & M4
- 3m, 10m, 25m
- WS, WD, T

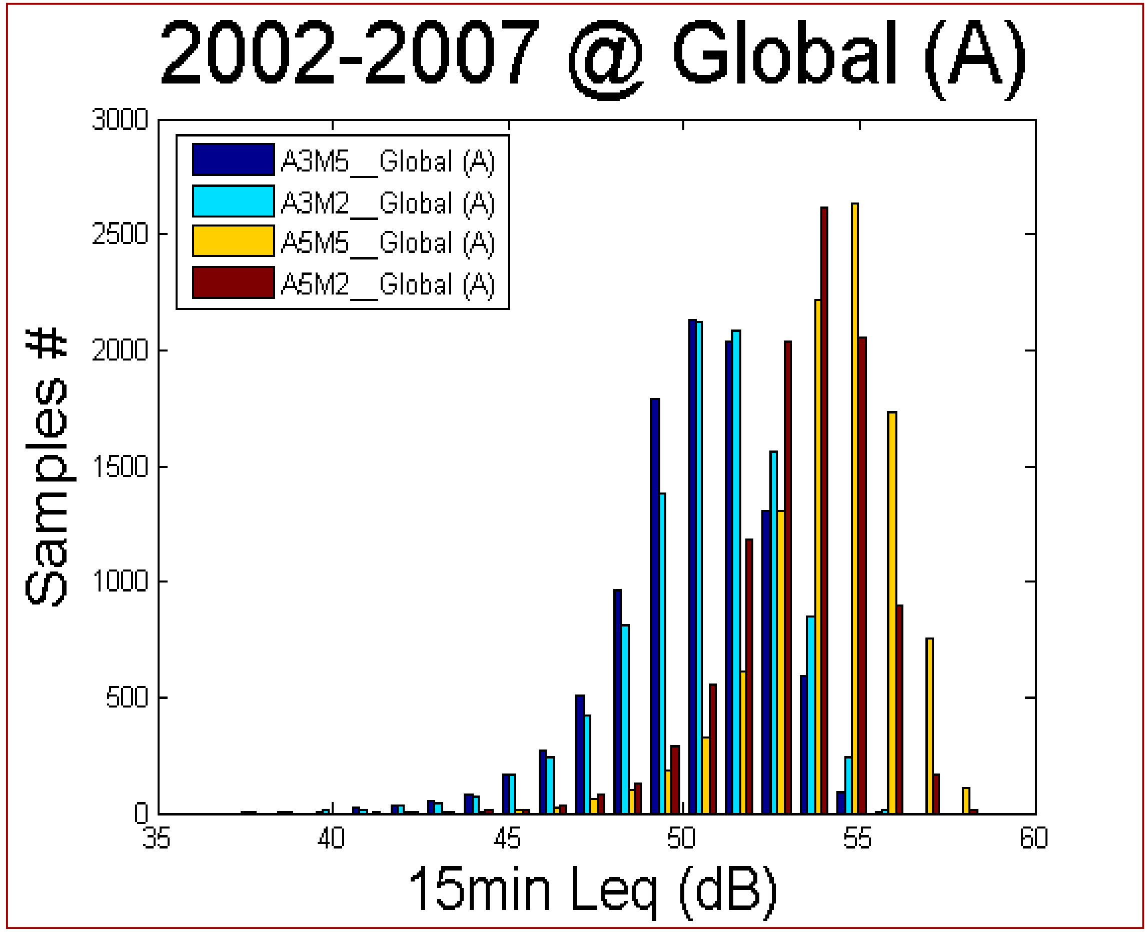
Acoustics :

- H=2m & 5m
- A1, A3 & A5
- Att_5 = A5-A1
- Att_3 = A3-A1



Space and time representativeness

> Leq_{15min}
> A3 // A5
> 2m // 5m
> Global(A)



A3M5 (A) : M=50.3 dB(A), Std=2.2 dB(A)

A3M2 (A) : M=50.7 dB(A), Std=2.3 dB(A)

A5M5 (A) : M=54.1 dB(A), Std=1.9 dB(A)

A5M2 (A) : M=53.2 dB(A), Std=1.9 dB(A)

Comments :

- Influence of the microphone *localization*…
- … and influence of the microphone *height*…
- …on *mean* and *std* values !

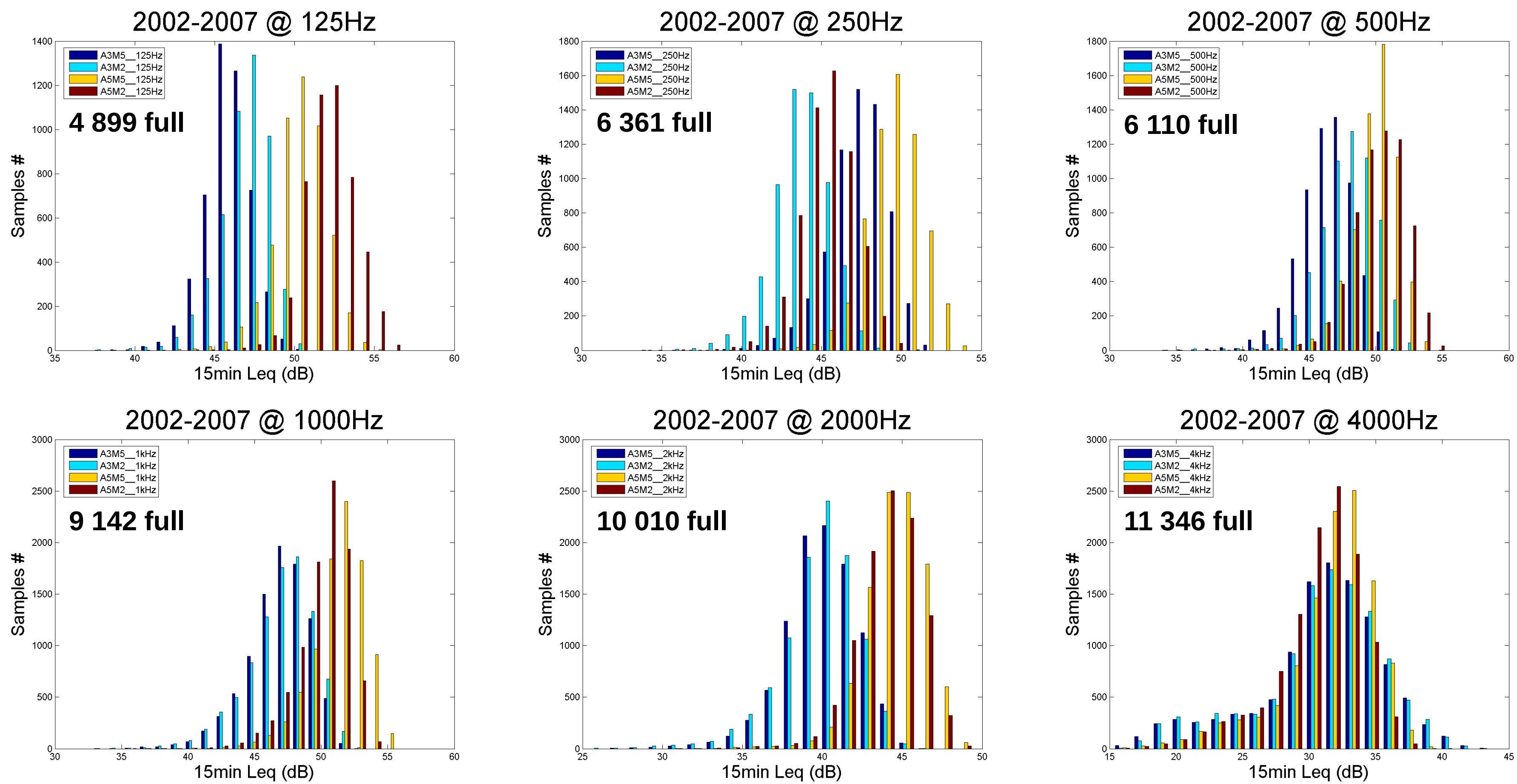
- Observations for Global(A)…
- … but significant discrepancies between frequencies (octave bands)

Space and time representativeness

> Leq_{15min}
> A3 // A5
> 2m // 5m
> Octave bands

Mean and Std values – examples :

	125Hz oct. band	1kHz oct. band
A3M5	m=46.0dB, std=1.4dB	m=46.9dB, std=2.4dB
A3M2	m=47.0dB, std=1.6dB	m=47.1dB, std=2.5dB
A5M5	m=50.3dB, std=1.6dB	m=51.3dB, std=2.0dB
A5M2	m=52.1dB, std=1.5dB	m=50.1dB, std=1.9dB



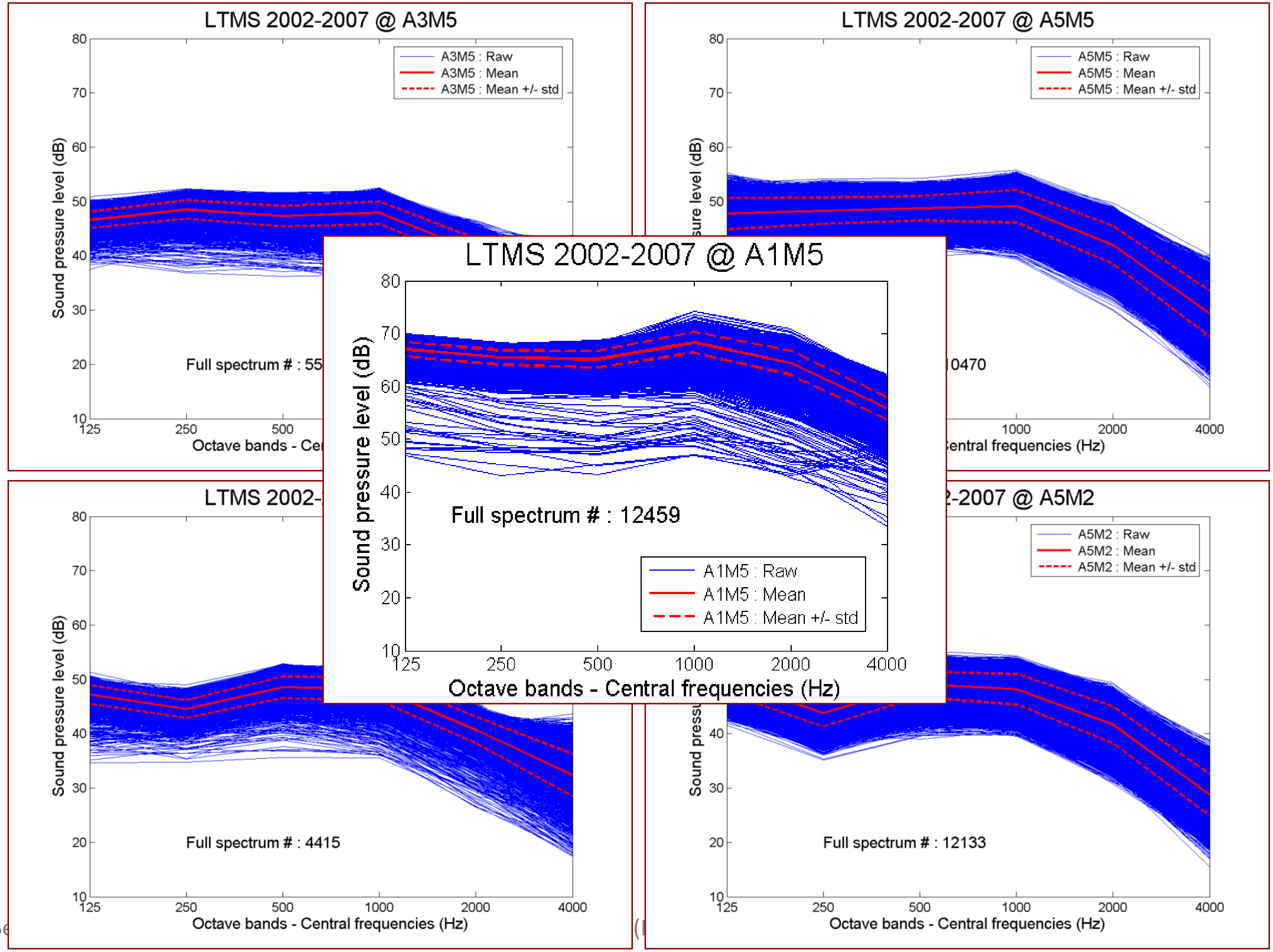
LTMS – SPL dispersion

Valley (A3)

Plateau (A5)

H = 5m

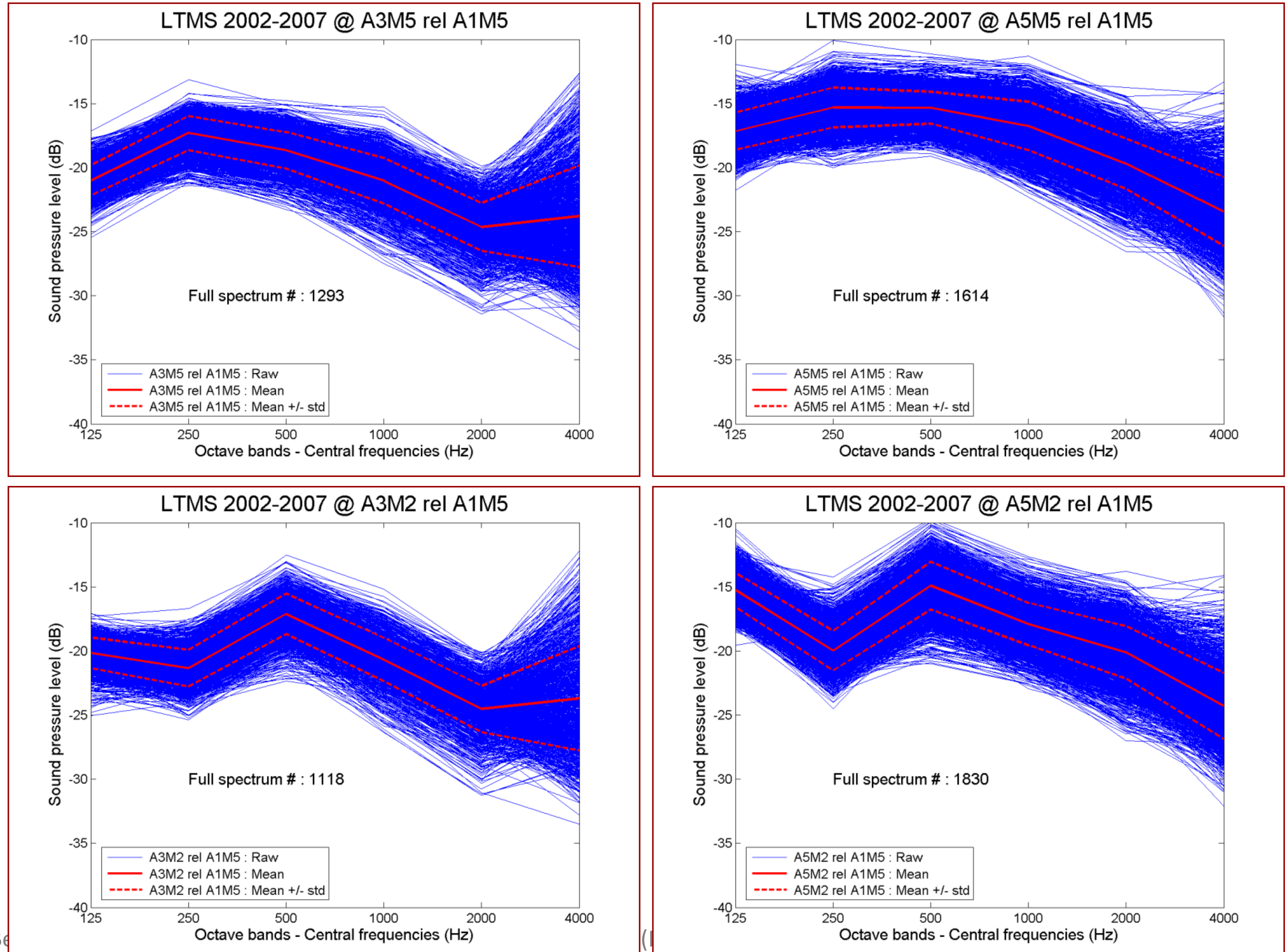
H = 2m



SPL rel. ref. microphone > propagation effects (excess att.)

Valley (A3) | Plateau (A5)

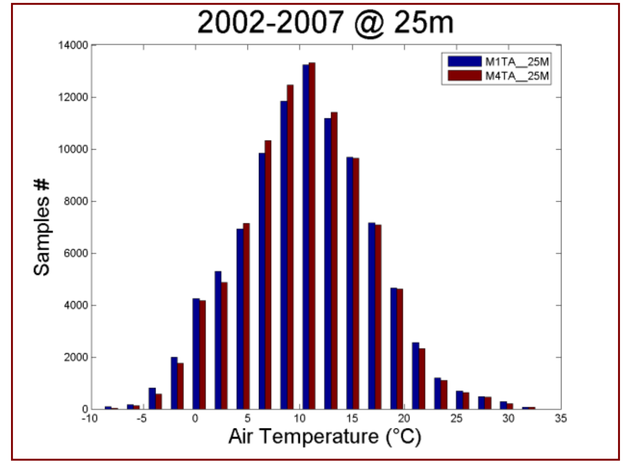
H = 5m / H = 2m

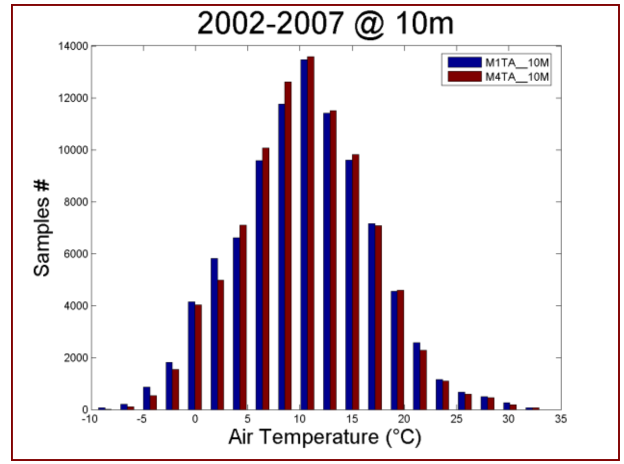


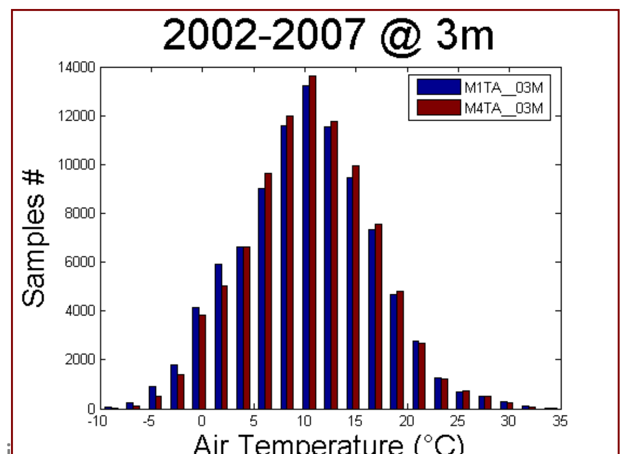
LTMS – Meteo

Space and time representativeness

> Air temperature
> M1 // M4
> 3m // 10m // 25m





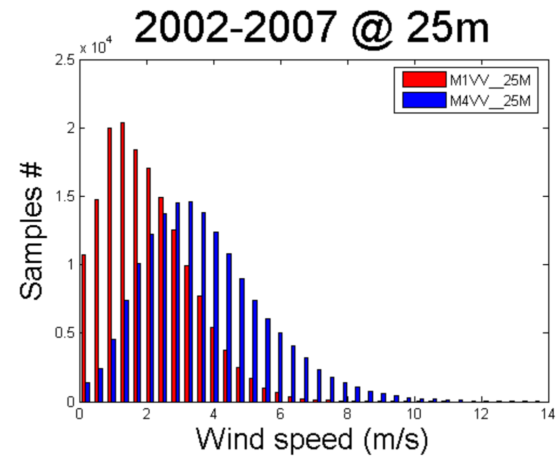


Comments :

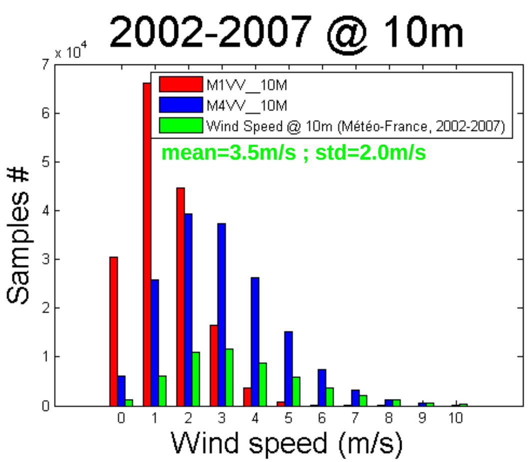
- Same behavior ∀ Mi and ∀ height…
- … but vertical profiles between M1 and M4 can be significantly different for some samples !
- Example: No wind + sunny >> river effect (plateau/vallée)

Space and time representativeness

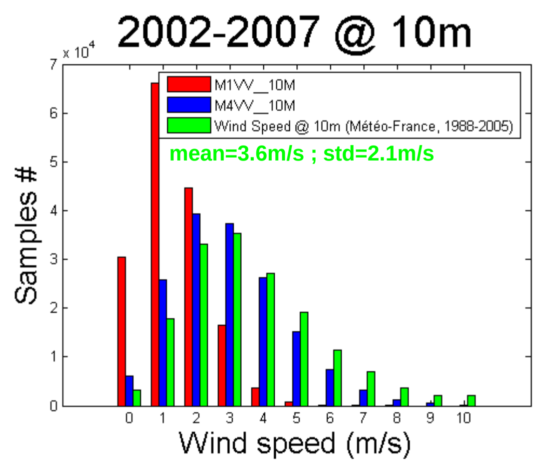
> Wind speed
> M1 // M4
> 3m // 10m // 25m

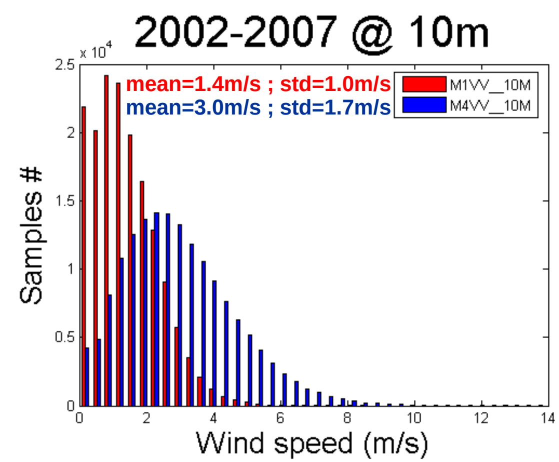


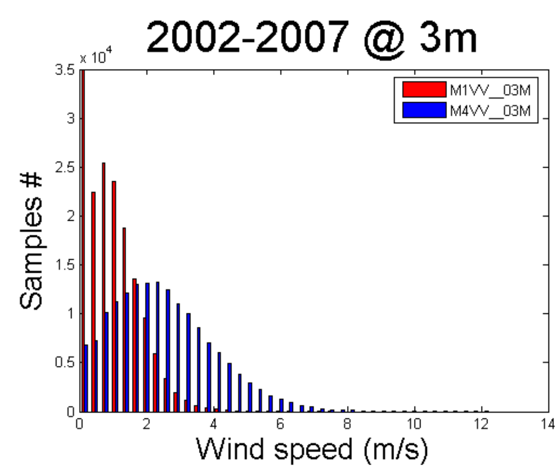
> + MF 2002-2007 (hourly)



> + MF 1988-2005 (hourly)







Comments :

- Different behavior regarding height…
- … but more noticeable for M1 (local effect)…
- … leading to significantly different vertical profiles…
- … and different SPL predictions ?

Space and time representativeness

> Wind direction
> M1 // M4
> 3m // 10m // 25m

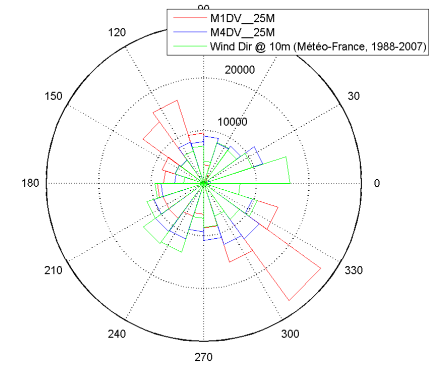
> + comparison with Météo-France measurements, 10km South-East from LTMS, hourly data, 10m high, 2002-2007 period (6 years)

> idem, 1988-2007 period (20 years)

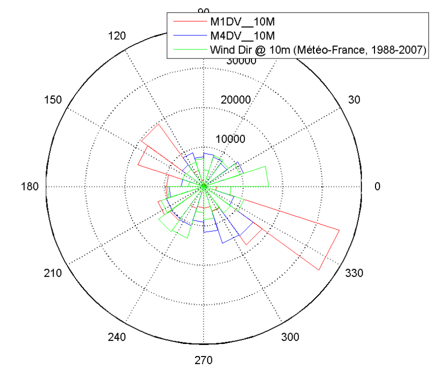
Comments :

- M1: Canyon effect for wind direction
- M4: Also a slight "site effect" (regarding M-F data)
- M1 // M4 // M-F: Influence on SPL predictions ?

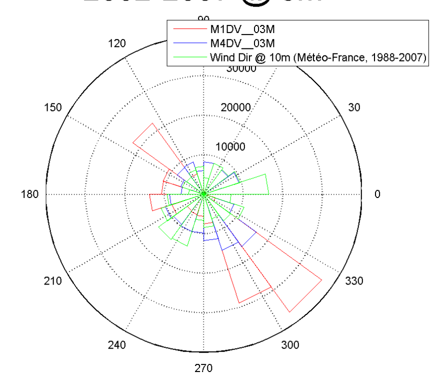
2002-2007 @ 25m



2002-2007 @ 10m



2002-2007 @ 3m



Meteo conditions: From wind and temperature observables…

> no atmospheric turbulence

$$n(r,\theta,z) \cong n(z) = \frac{c(z)}{c_0} = \boxed{\frac{\langle c(z)\rangle}{c_0}} + \mu$$

> mean refraction (*e.g.* 15min samples)

$$\langle c(z)\rangle = \sqrt{\gamma \cdot R \cdot \langle T(z)\rangle} + \langle V(z)\rangle \cdot cos\theta$$

> Hyp: lin-shaped vertical profiles for wind and temperature

$$\langle T(z)\rangle = a_T \cdot z + T_0$$

$$\langle V(z)\rangle = a_V \cdot z$$

… to influent parameters a_{Tp} and a_{Vp}

> relative influence of wind/temperature effects

> Mean refraction parameters for lin-shaped profiles (or log-shaped profiles at z = 1m)

$$\frac{\partial\langle c(z)\rangle}{\partial z} \approx \frac{1}{2} \cdot \frac{\gamma \cdot R}{c_0} \cdot \frac{\partial\langle T(z)\rangle}{\partial z} + \frac{\partial\langle V(z)\rangle}{\partial z} \cdot cos\alpha$$

$$\frac{\partial\langle c(z)\rangle}{\partial z} \approx \underbrace{\frac{1}{2} \cdot \frac{\gamma \cdot R}{c_0} \cdot a_T}_{a_{Tp}} + \underbrace{a_V \cdot cos\alpha}_{a_{Vp}}$$

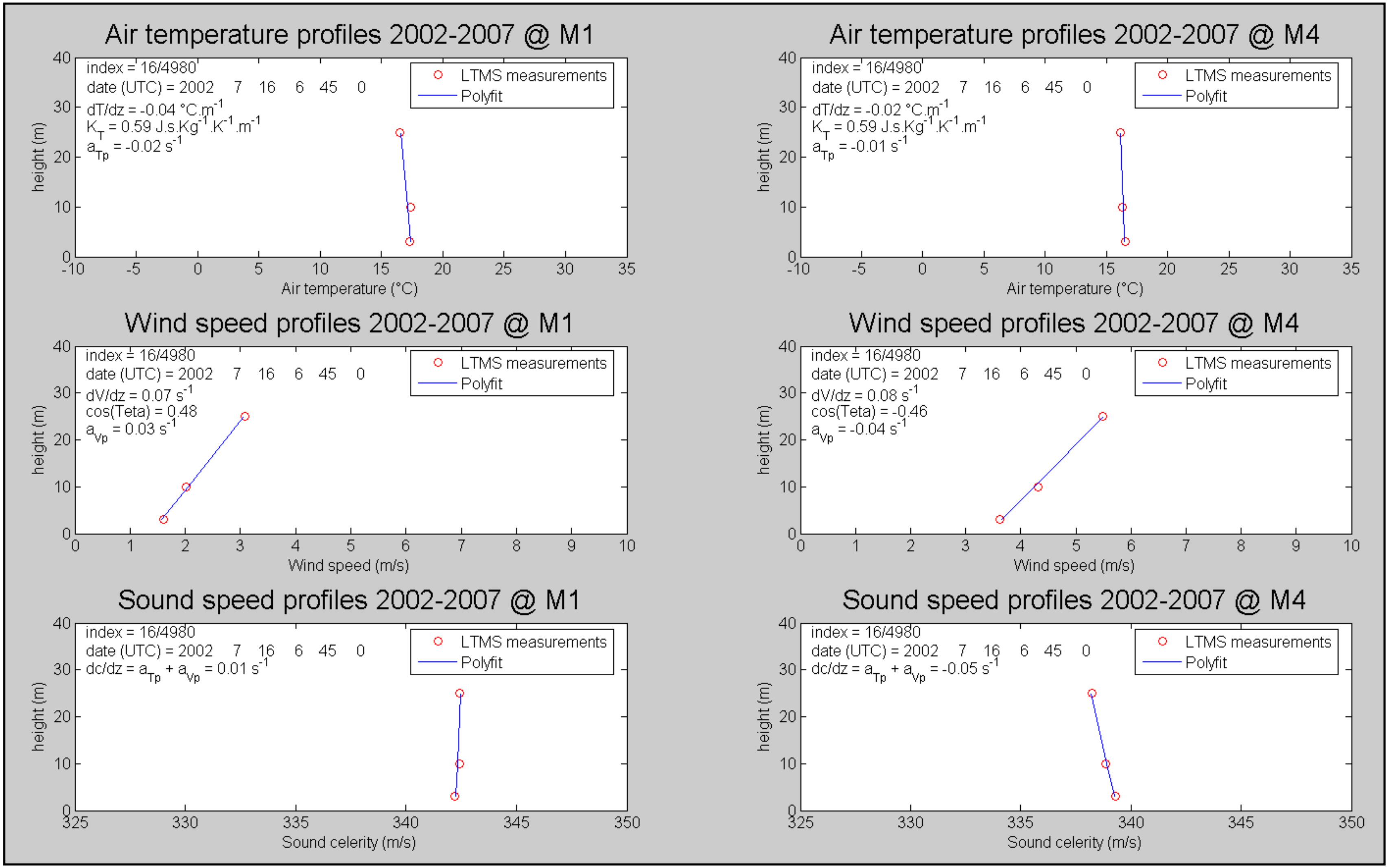
LTMS – Propagation conditions

Valley (M1) | Plateau (M4)

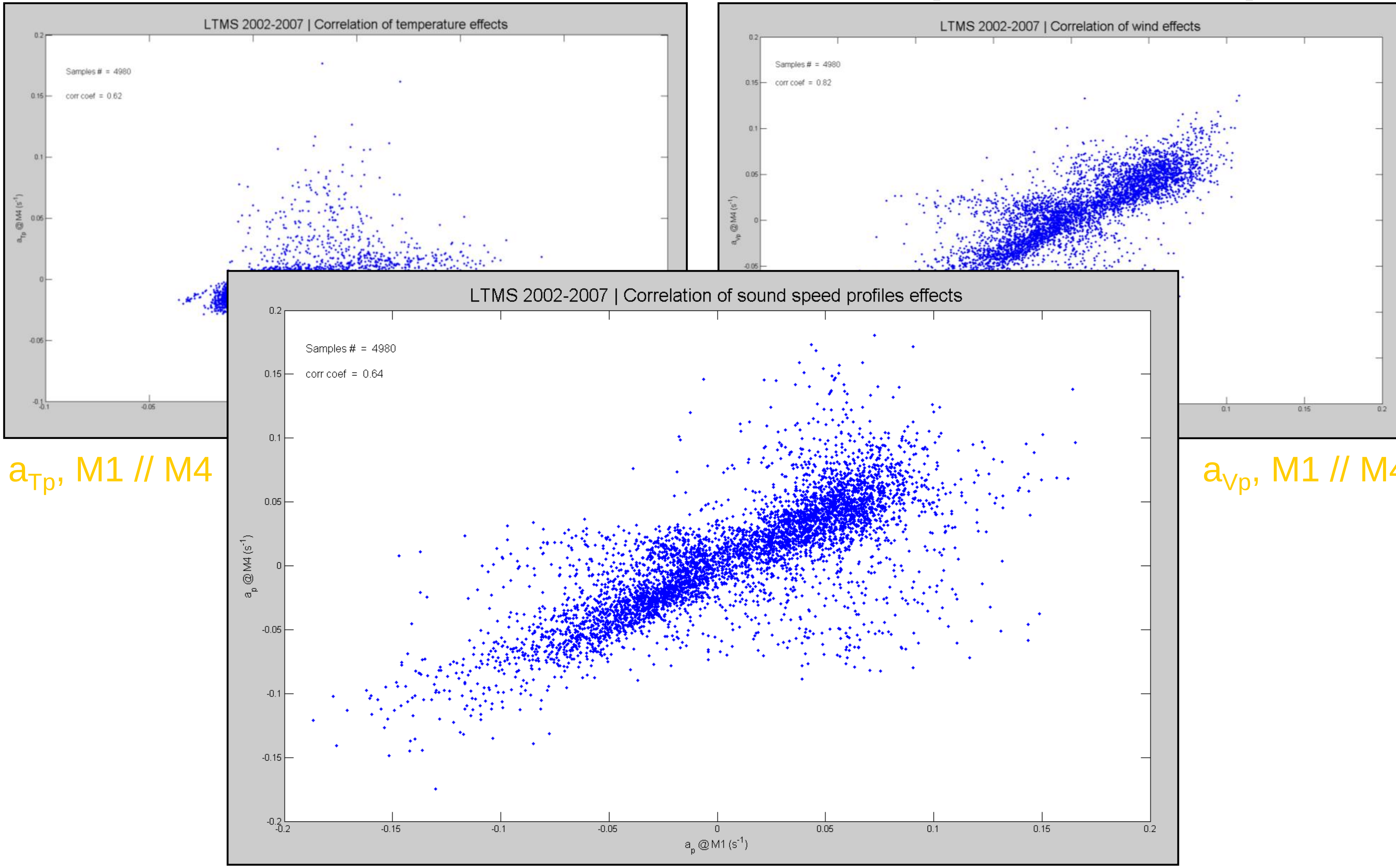
T(z)

W(z)

c(z)



LTMS – Site effect (meteo)

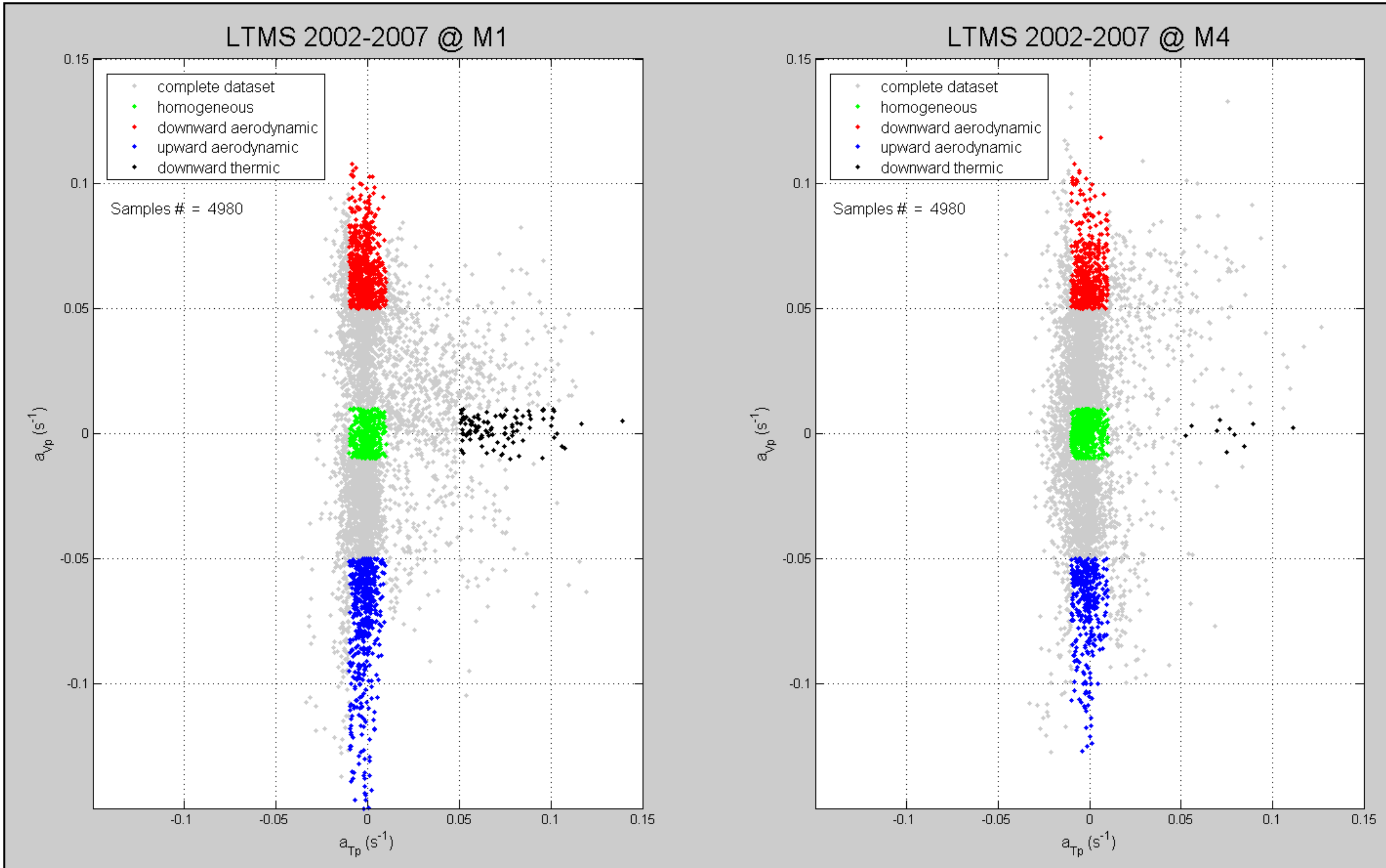


a_{Tp}, M1 // M4

a_{Vp}, M1 // M4

a_c, M1 // M4

LTMS – Data classification



Méthode de classification

- Algorithme des *k-means* : minimise la somme des carrés des distances au sein de chaque groupe

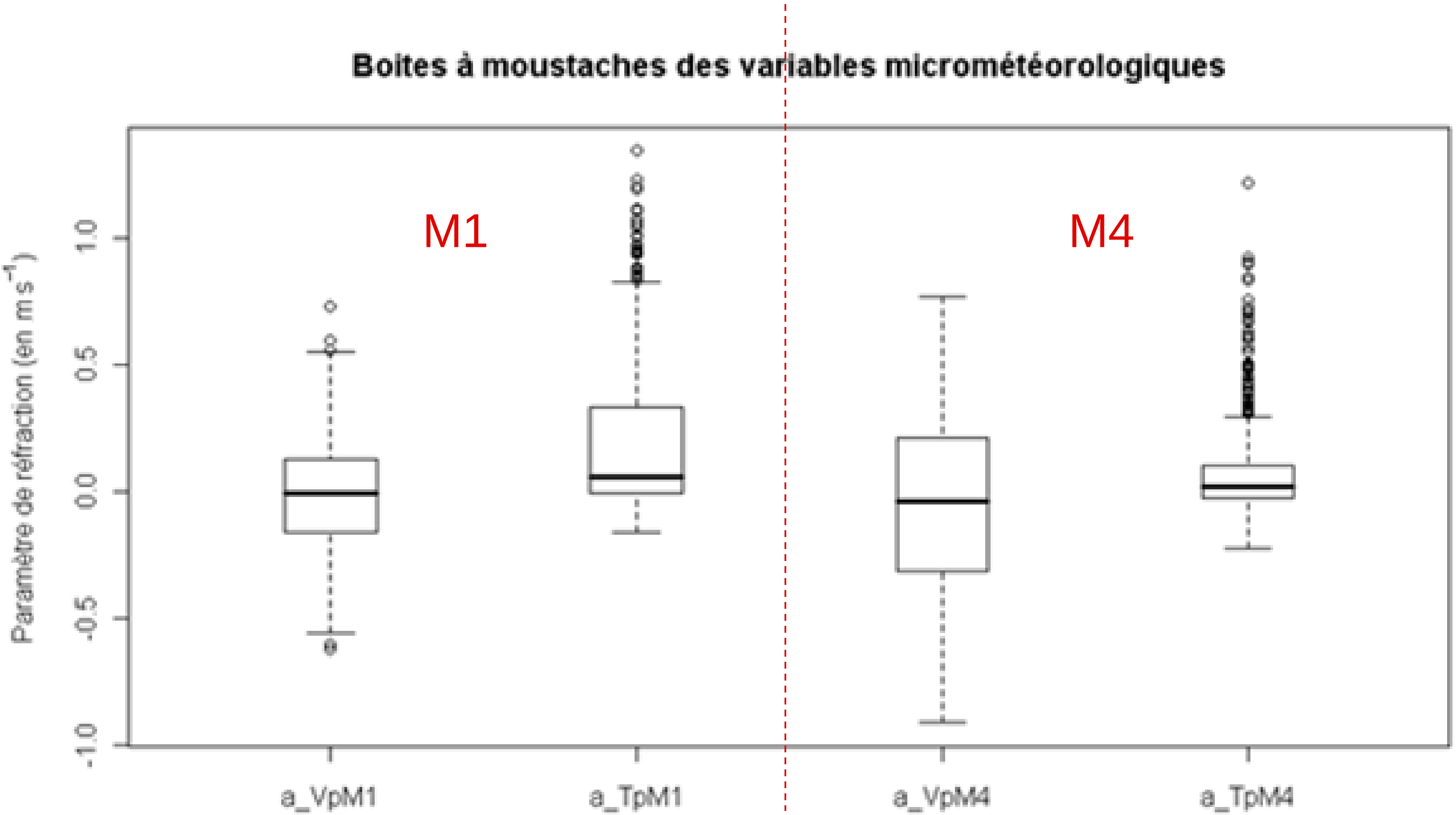
- Stratégie pour l'application à notre échantillon

  - Météo : 2 classifications utilisant respectivement les variables météo de M1 et M4, pour mettre en évidence l'*effet de site*
  - *Acoustique :* octaves 250Hz & 1kHz (cf supra), H=5m (idem H=2m, *Cf* infra)

  - 6 variables par classification : a_{Vp}, a_{Tp}, A3_250_5m, A3_1k_5m, A5_250_5m, A5_1k_5m

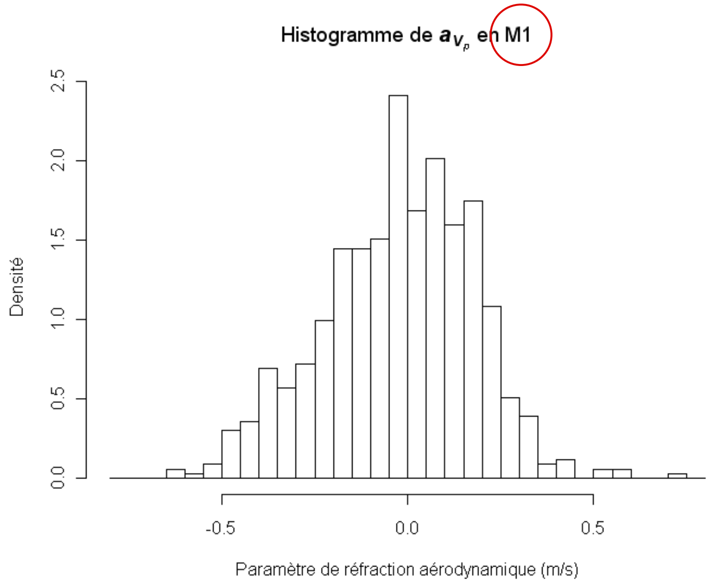
  - Variables centrées et réduites, puis pondérées
  - Partitionnement en 4 classes
  - Utilisation de la *silhouette* pour juger de l'appartenance à une classe

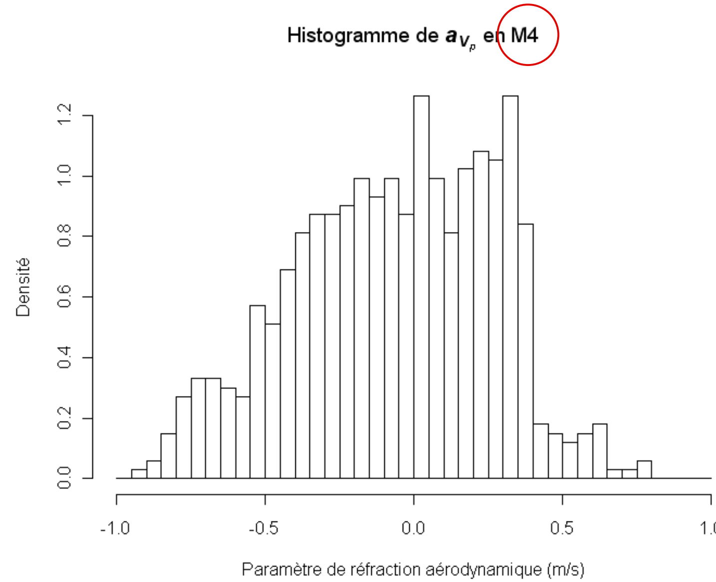
Effet de site sur a_Vp & a_Tp



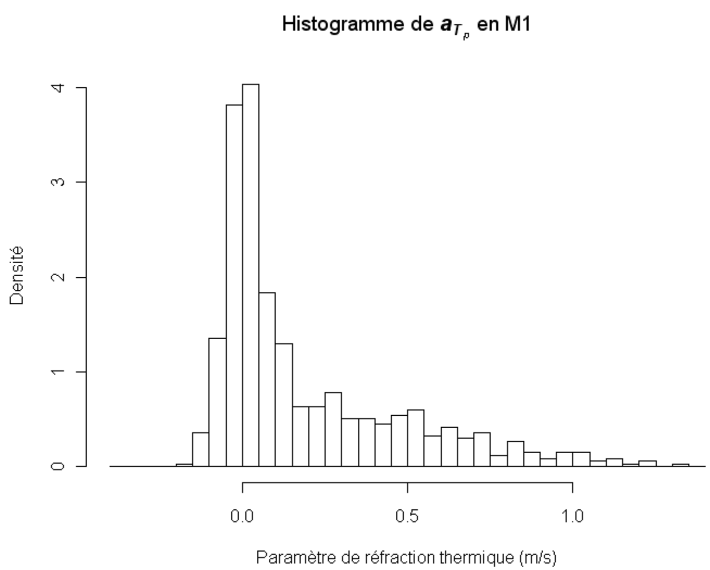
Effet de site sur a_{Vp} & a_{Tp}

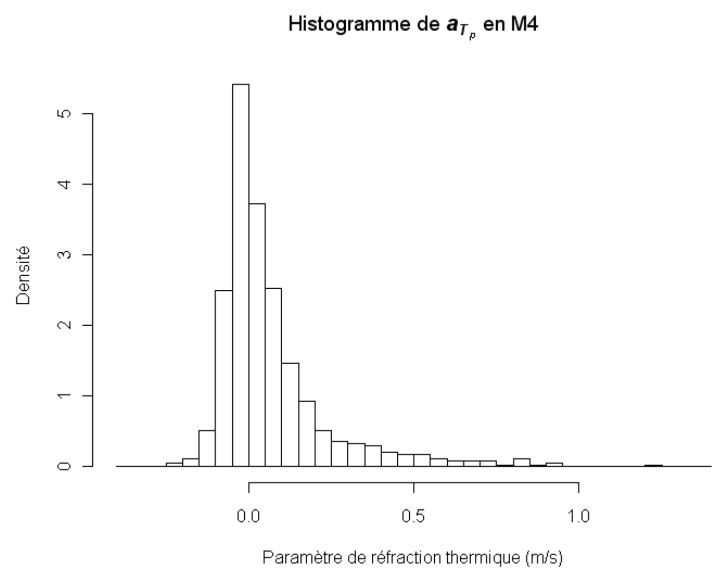
a_{Vp}



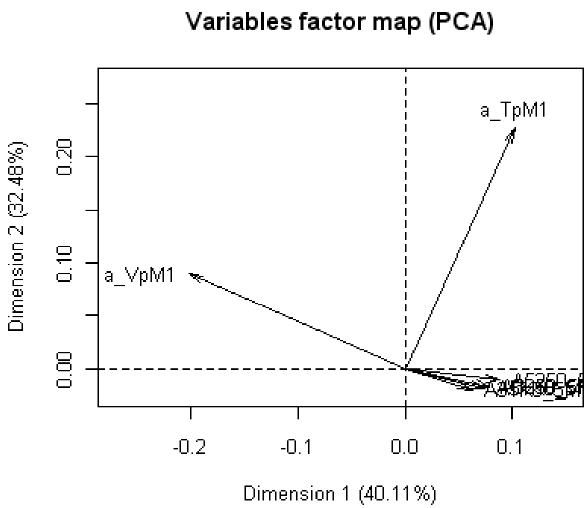


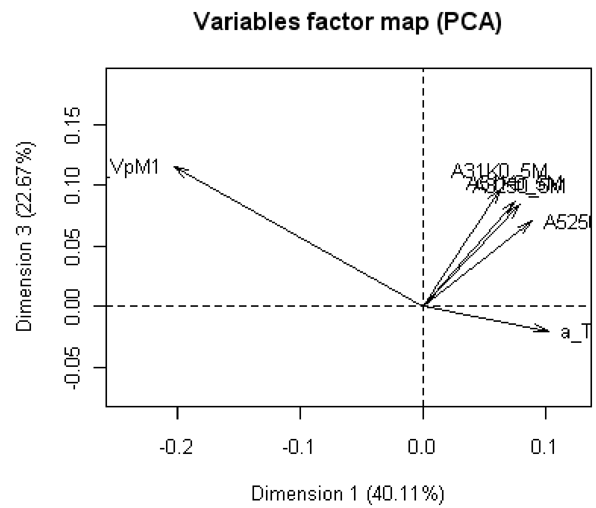
a_{Tp}

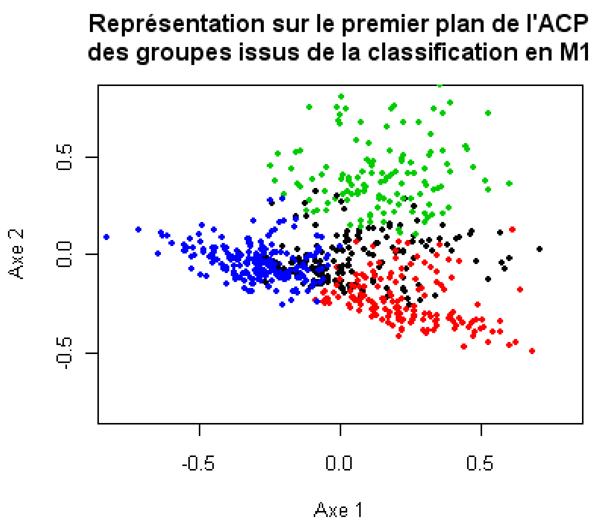


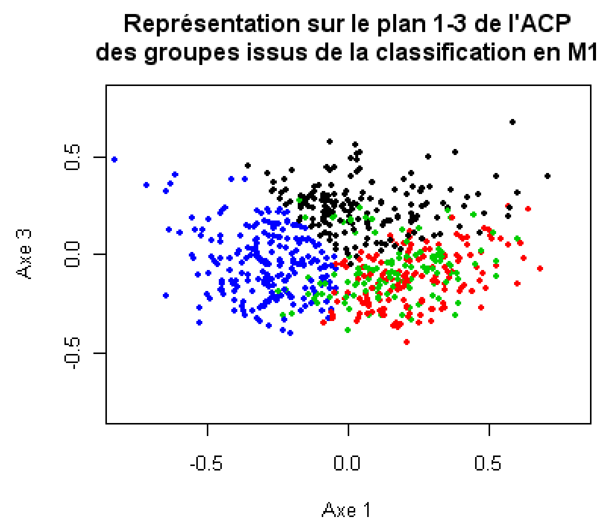


Présentation des résultats : représentation sur les premiers plans de l'ACP









Classification des régimes de propagation

- Objectif : déterminer les situations « types »

- Echantillon de 665 observations « complètes », c'est-à-dire pour lesquelles les données de trafic sont disponibles et les variables suivantes sont renseignées

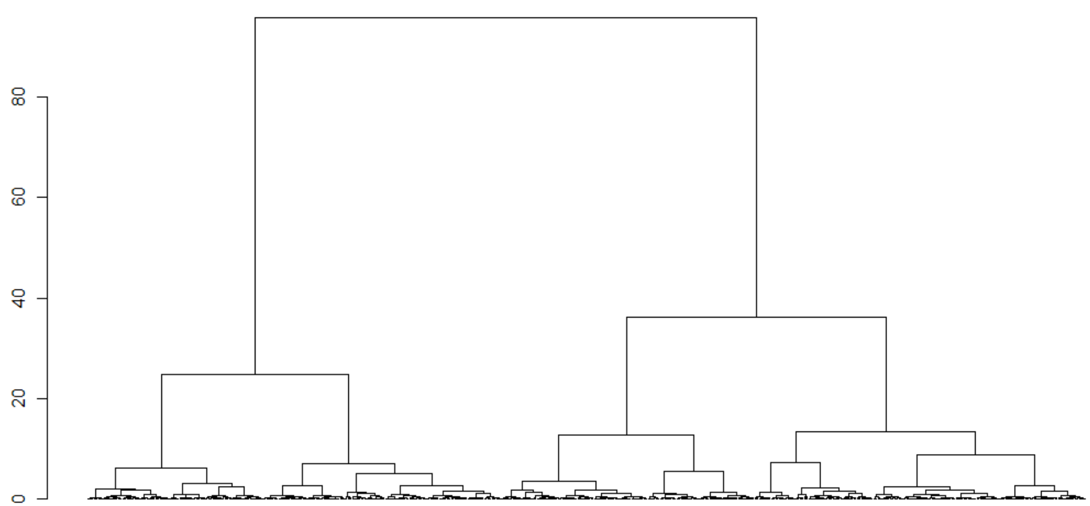
- Variables

  - Acoustiques : atténuation sonore (en dB) à 250Hz et 1kHz aux mâts A3 et A5, relativement au mât A1

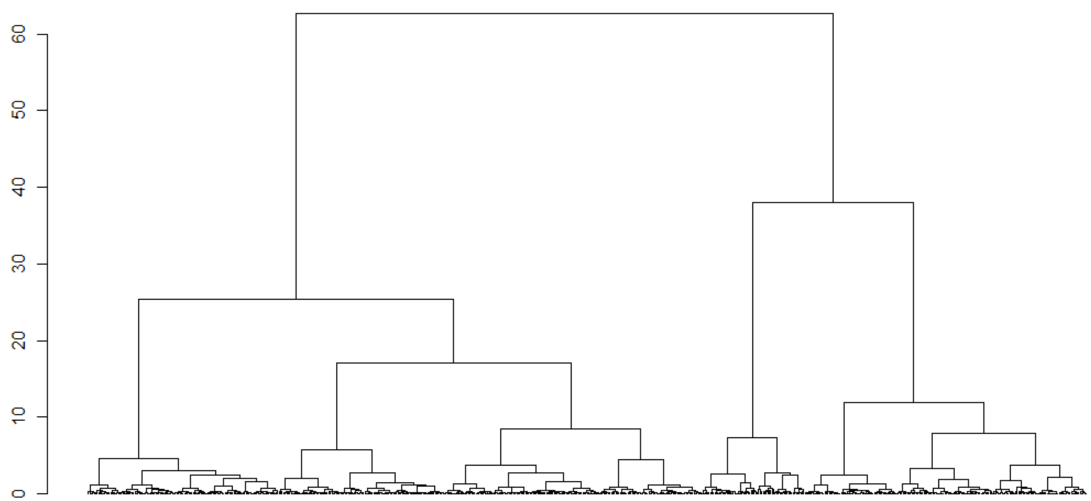
  - Météorologiques : paramètre de réfraction thermique pondéré $\boldsymbol{a_{T_p}}$ et paramètre de réfraction aérodynamique projeté $\boldsymbol{a_{V_p}}$ en M1 et M4 en $m.s^{-1}$

Classification météo « en aveugle »

Dendrogramme pour la classification en M1



Dendrogramme pour la classification en M4



> N classes ???

Méthode de classification

- Algorithme des *k-means* : minimise la somme des carrés des distances au sein de chaque groupe

- Stratégie pour l'application à notre échantillon

  > Météo : 2 classifications utilisant respectivement les variables météo de M1 et M4, pour mettre en évidence l'*effet de site*

  > *Acoustique :* octaves 250Hz & 1kHz (cf supra), H=5m (idem H=2m, *Cf* infra)

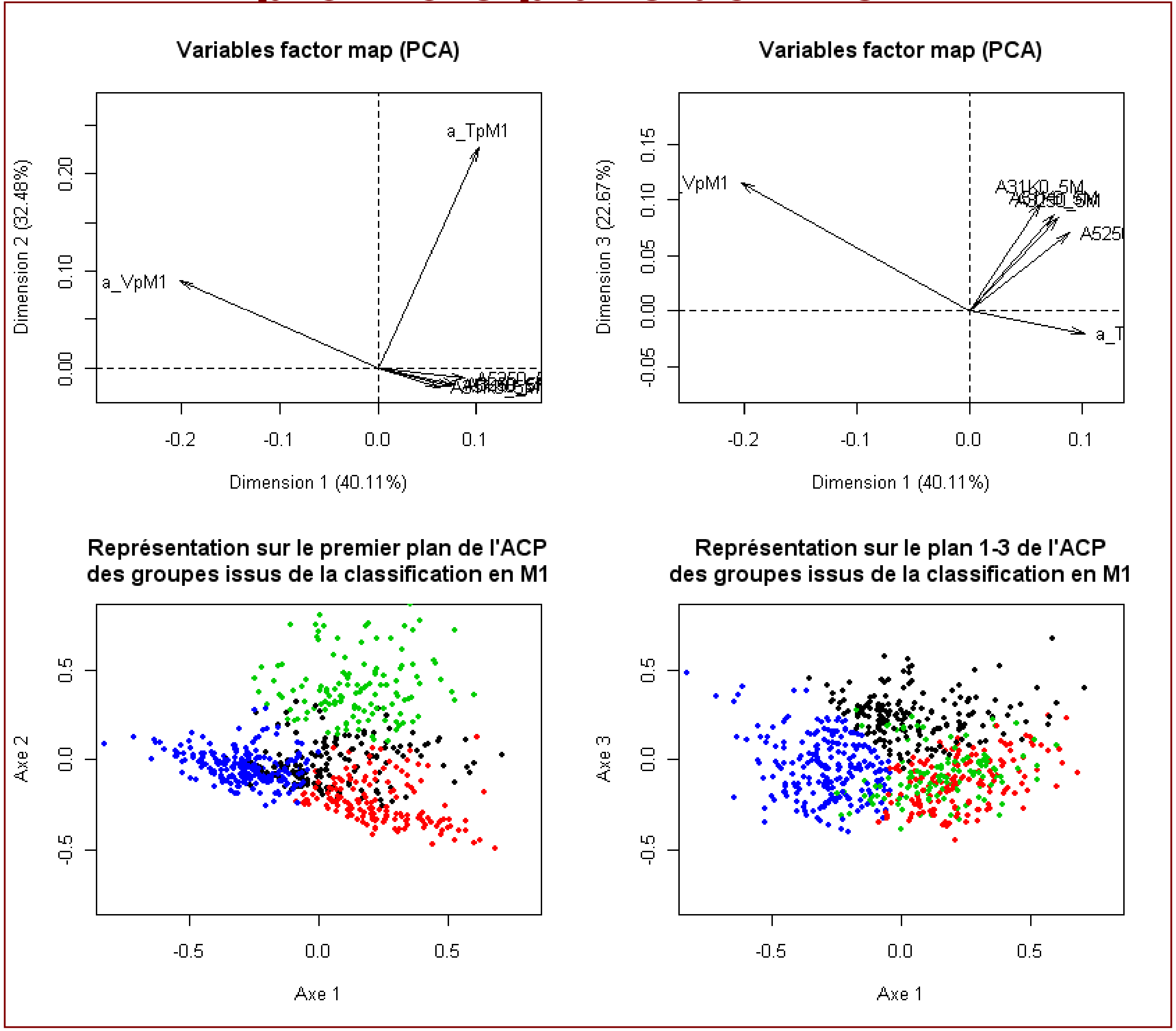
  > 6 variables par classification : a_{Vp}, a_{Tp}, A3_250_5m, A3_1k_5m, A5_250_5m, A5_1k_5m

  > Variables centrées et réduites, puis pondérées

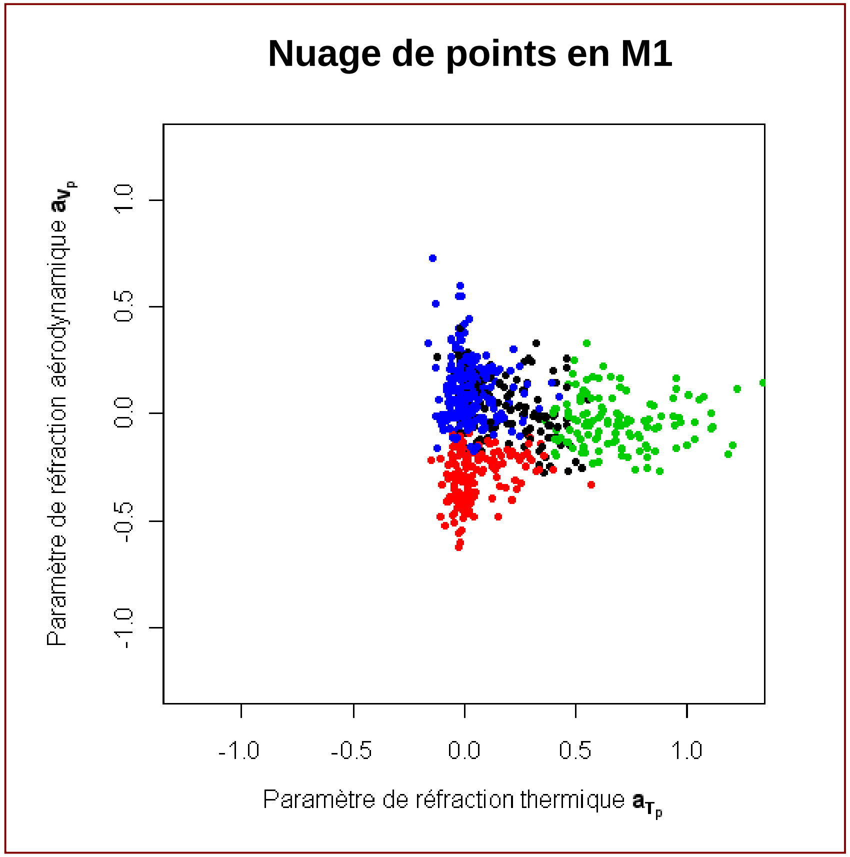
  > Partitionnement en 4 classes

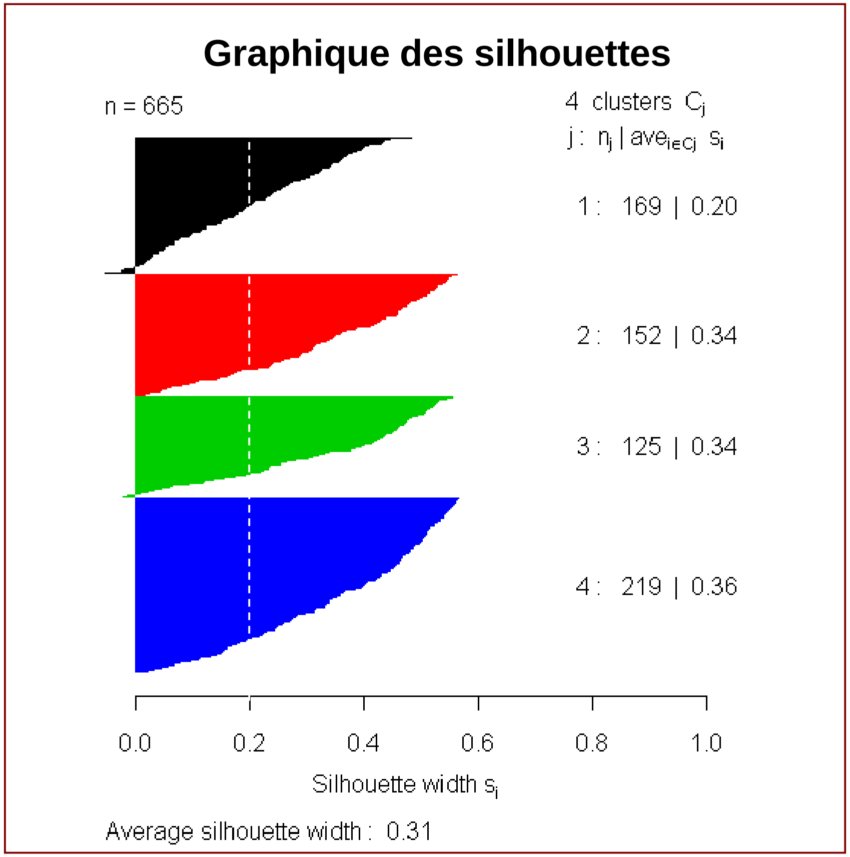
  > Utilisation de la *silhouette* pour juger de l'appartenance à une classe

Présentation des résultats : représentation sur les premiers plans de l'ACP



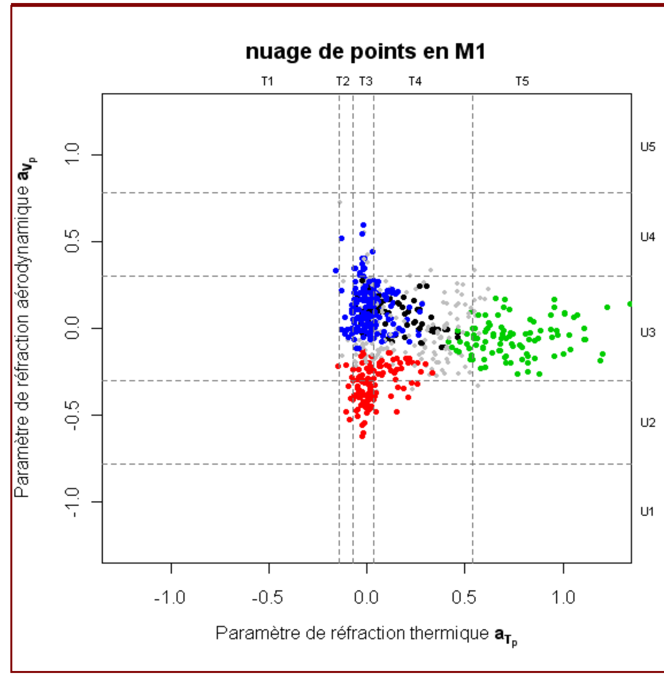
Présentation des résultats : représentation en fonction des conditions météo





> Prochaine étape : on enlève les observations pour lesquelles la largeur de la silhouette est inférieure à 0.2

Classification… … using M1



> Multidimensional analysis ("k-means")

> H=5m (idem H=2m)

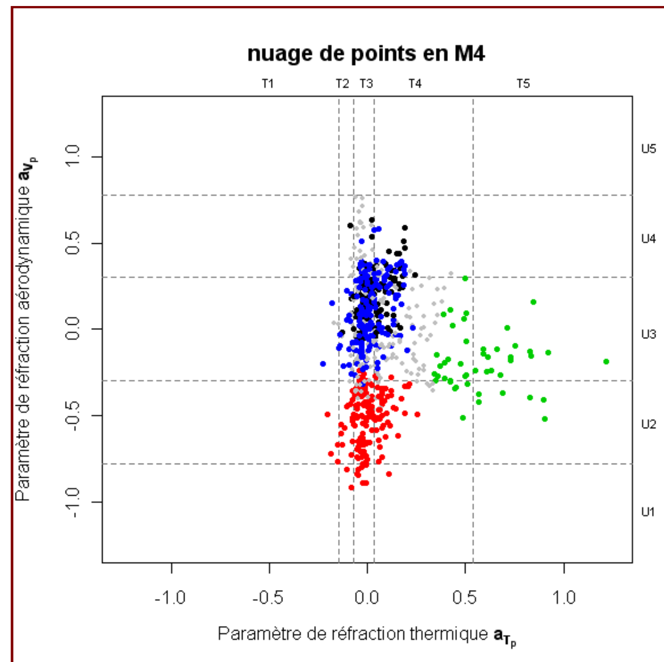
> <u>6 variables</u>: a_{Vp}, a_{Tp}, A3_250_5m, A3_1k_5m, A5_250_5m, A5_1k_5m

> Meteo plane (a_{Tp} & a_{Vp})

> 665 "full" lines

> + UiTi table (≃ WiSi table from Harmonoise)

… using M4

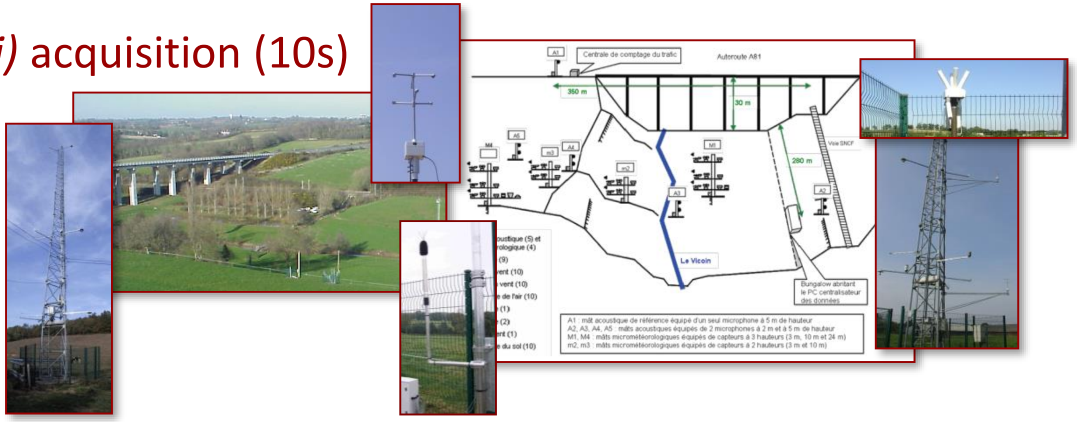


<u>Comments</u> :

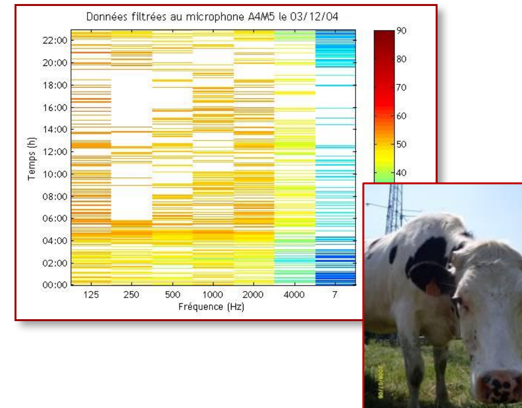
- The choice of meteo tower have a great impact on the classification of propagation conditions
- Long-term measurements are condensed in a small region of UiTi (or WiSi) tables
- >> the UiTi (or WiSi) classes need to be revised and take into account propagation conditions:
  - sound source and ground impedance characteristics
  - source height and source-receiver distance (geometry)
  - associated uncertainties for each class

LTMS_2002-2007 (synthesis)

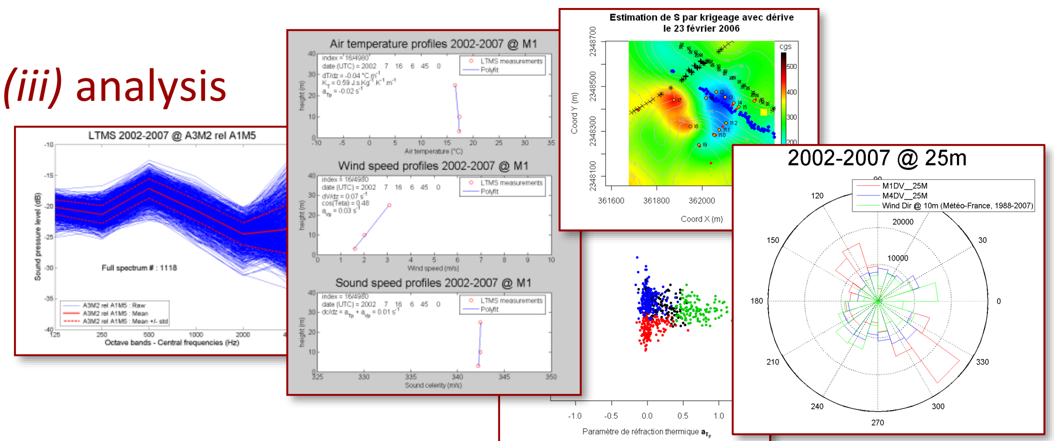
- *(i)* acquisition (10s)



- *(ii)* post-processing (15min)



- *(iii)* analysis



- *(iv)* valorisation

[Gauvreau App. Acoust. 2013]

http://ltms2002-2007.ifsttar.fr

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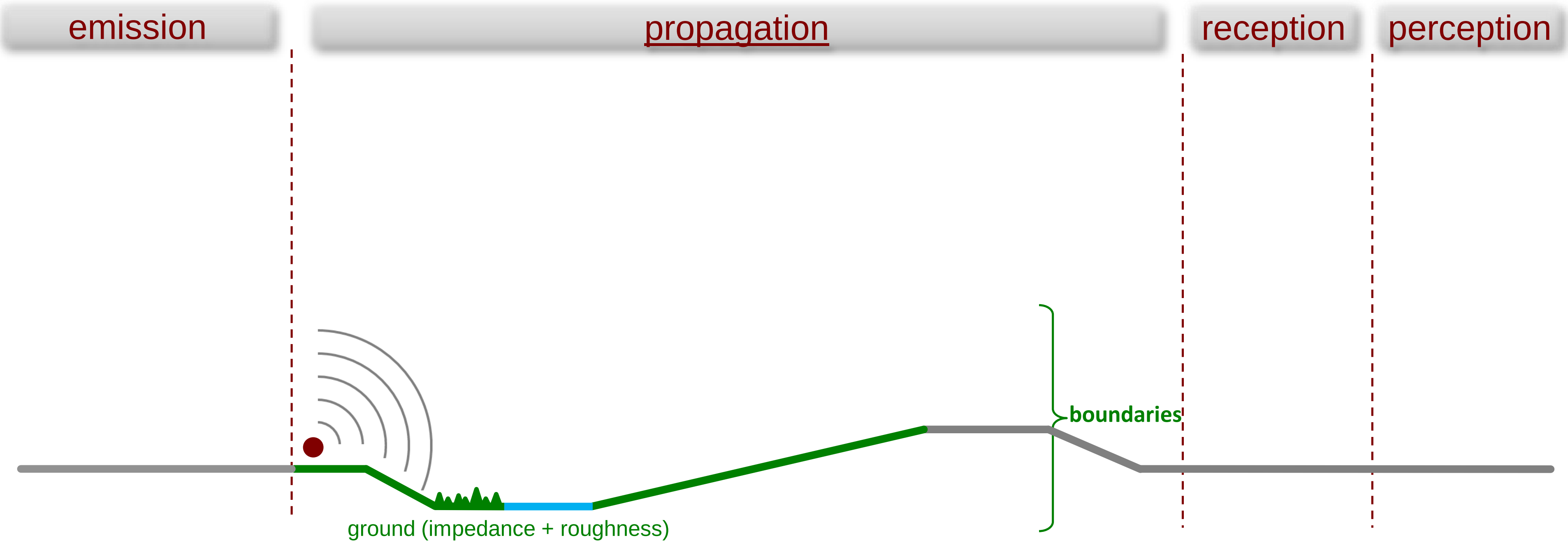
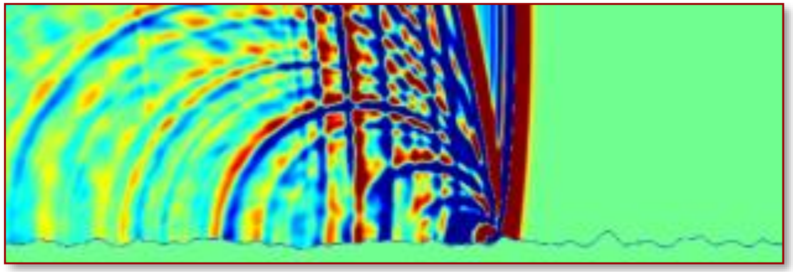
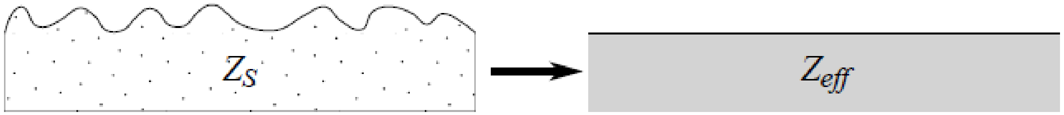


PhD Olivier Faure (2014)

- Ground roughness
  - is considered small compared to the wavelength of interest
  - induces scattering of the incident wave
  - modifies the ground effect
  - can generate a surface wave



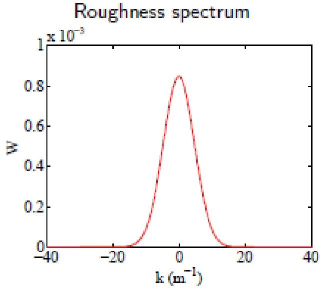
- Modelling of ground roughness effects by an effective impedance:

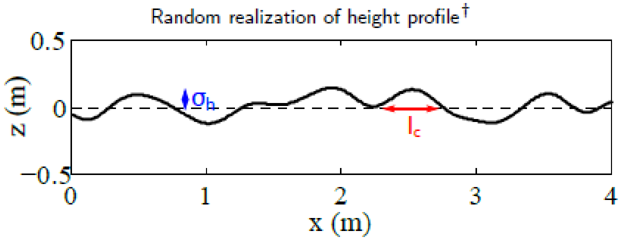


1D Gaussian Spectrum definition†

$$W(k) = \frac{\sigma_h^2 l_c}{2\sqrt{\pi}} e^{\frac{-k^2 l_c^2}{4}}$$

- *E.g.* $\sigma_h = 0.1$ m and $l_c = 0.3$ m:





- Experimental surfaces defined with a gaussian spectrum:
  - $\sigma_h = 0.05$ m
  - $l_c = 0.2$ m

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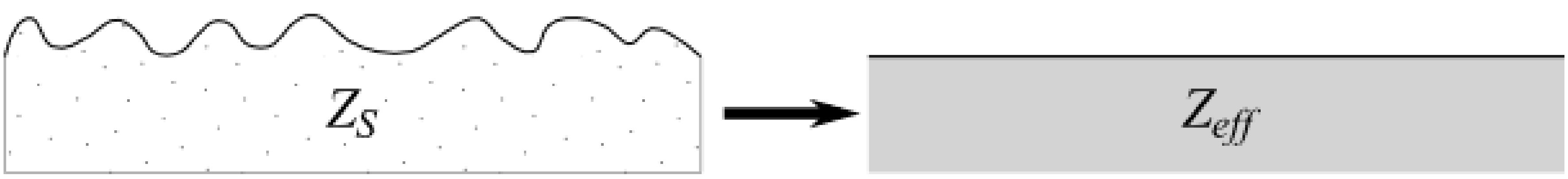
• Context : modelling of outdoor sound propagation in an heterogeneous medium.

• Realistic cases include :
- time variability of the propagation medium properties
- geometric irregularities due to the complexity of the ground
- measurement uncertainties

• Modelling the effects of small geometry irregularities compared to wavelength (« roughness ») using an effective impedance :



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- Boss model for a roughness formed by cylindrical scatterers[1]

$$1/Z_{eff} = \beta_{eff} = \beta_s + \beta_R(size, spacing, shape, etc.)$$

→ Experimentally[1] and numerically validated[2] (and impemented in time-domain methods)

- Model for a random roughness ?

→ Objectives : experimental validation of an effective impedance model for random roughness with measurements in semi-anechoic chamber

[1] P. Boulanger, K. Attenborough, Q.Qin, "Effective impedance of surfaces with porous roughness: Models and data", Journal of the Acoustical Society of America, 117(3), 1146-1156 (2005).
[2] O. Faure, B. G., F. J., and P. L., Effective impedance models for rough surfaces in time-domain propagation methods, In Proceedings of Internoise 2013, Innsbruck, Austria.

I.1 – Definition

• In electromagnetism, an effective impedance model for rough surfaces is obtained using the Small Perturbation Method (MPP), taking into account the **roughness spectrum** of the surface and its statistical properties[3]

• Transposed to acoustics for an absorbing rough surface :

$$1/Z_{eff} = \beta_{eff} = \beta_S + \int_{-\infty}^{+\infty} \frac{d\kappa'}{k_0 k_z(\kappa')} \left(k_0^2 - \kappa\kappa'\right) W\left(\kappa - \kappa'\right) \quad \text{with} \quad k_z(\kappa) = \sqrt{k_0^2 - \kappa^2}$$

• Models the mean effects of ground roughness on sound propagation

• Reformulation possible to get rid of the pole[3] for an easy numerical integration

• Used with the **Weyl-Van der Pol formula** for obtaining analytical solutions

[3] Y. Brelet and C. Bourlier, "SPM numerical results from an effective surface impedance for a one-dimensional perfectly-conducting rough sea surface," *Progress in Electromagnetics Research-pier*, vol. PIER 81, pp. 413–436, 2008.

I. MPP effective impedance model

I.2 – Roughness power spectrum

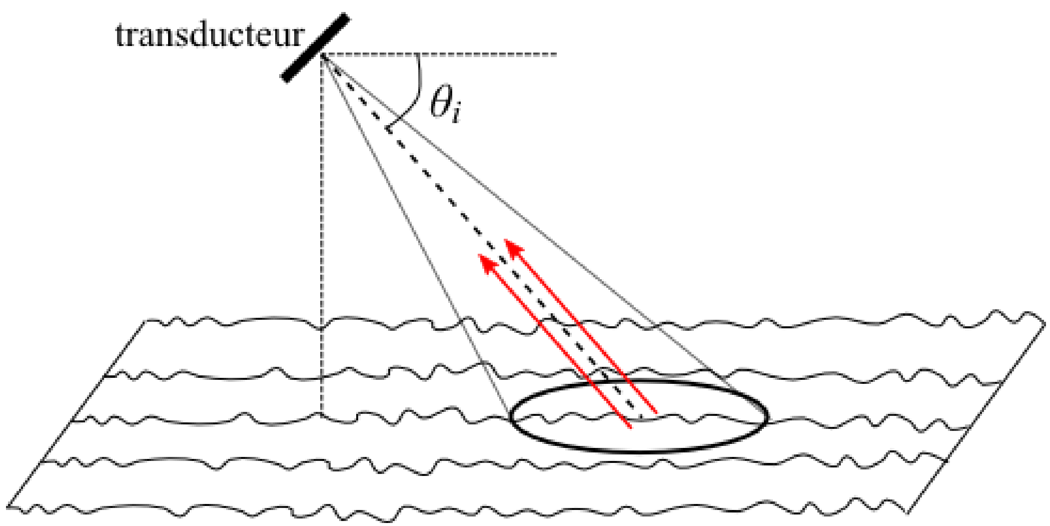
- For an area of a surface whose height profile ζ is known :

$$W(k_x, k_y) = \left|\Im\left[\zeta(x, y)\right]\right|^2$$

- For a surface statistically defined by an autocorrelation function C_ζ :

$$W(k_x, k_y) = \iint e^{-i\vec{k}.\vec{x}} C_\zeta(x, y)\,dxdy$$

- For a rough sea surface or a rough ground, the roughness power spectrum can be estimated by backscattering measurements[4]



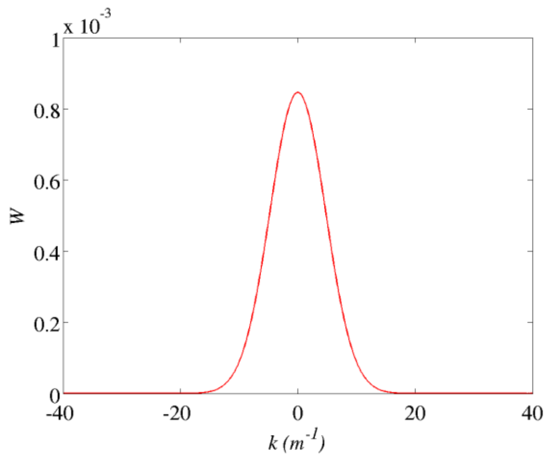
[4] M.L.Oelze, J.M. Sabatier, R..Raspet, “Application of an acoustic backscatter technique for characterizing the roughness of porous soil”, Journal of the Acoustical Society of America, 111(4), 1565-1577 (2002).

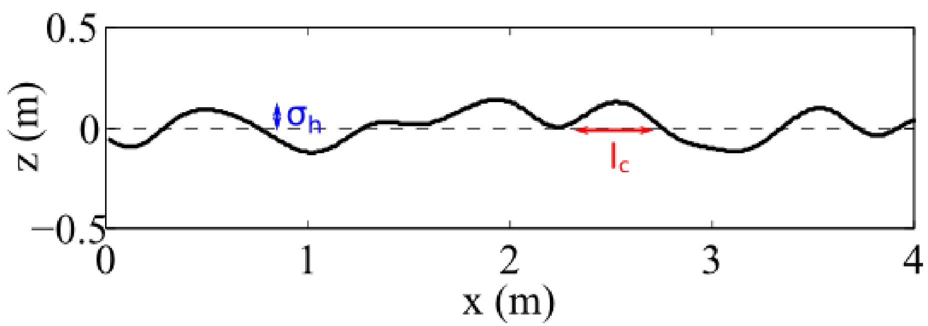
II.1 – Gaussian roughness spectrum

- A 1D gaussian roughness spectrum is defined by :

$$W(K) = \frac{\sigma_h^2 l_c}{2\sqrt{\pi}} e^{-\frac{K^2 l_c^2}{4}}$$

e.g. σ_h=0.1m and l_c=0.3m





- Experimental rough surfaces defined with a gaussian spectrum :

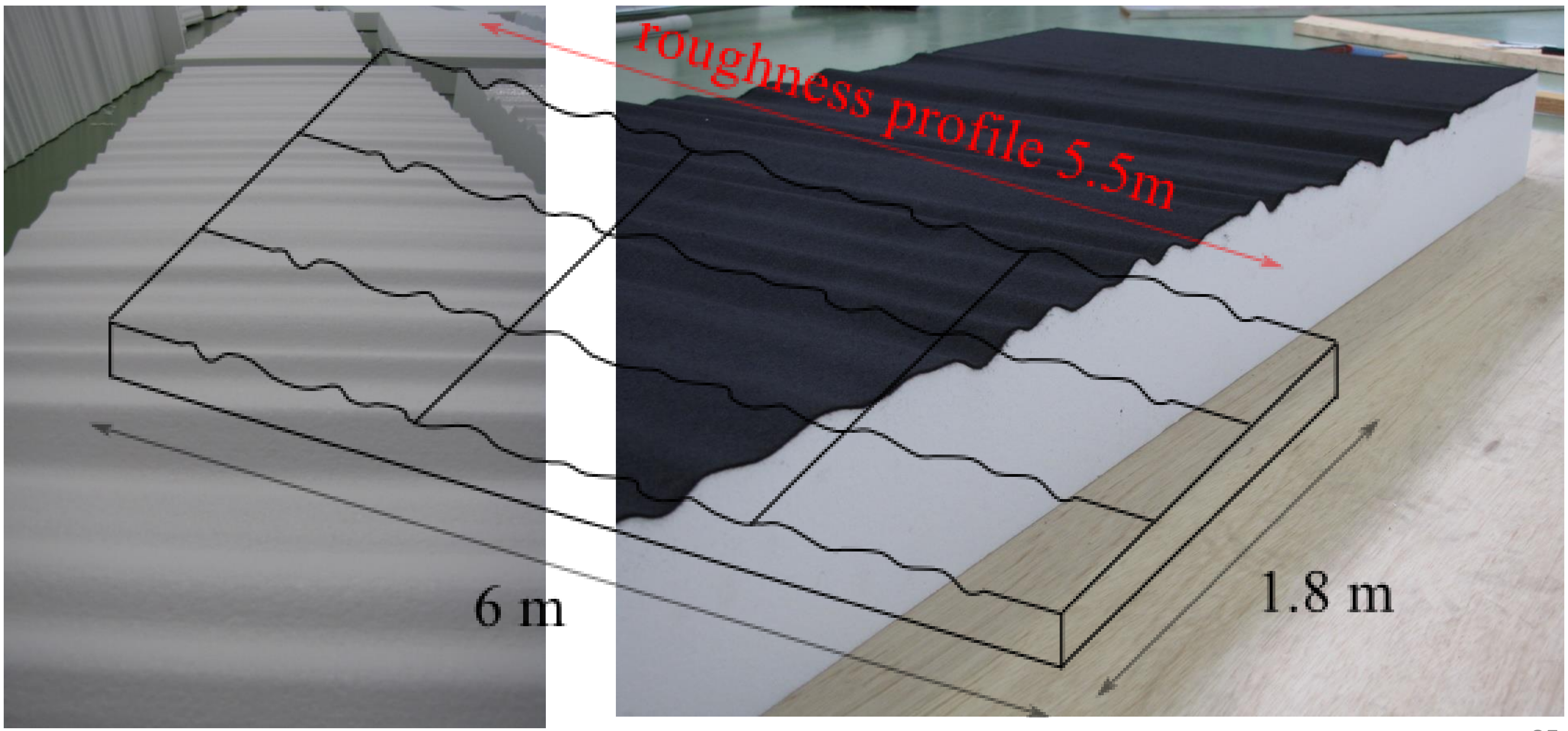
-σ_h=0.05m

- l_c=0.2m

II.2 – Rough surfaces

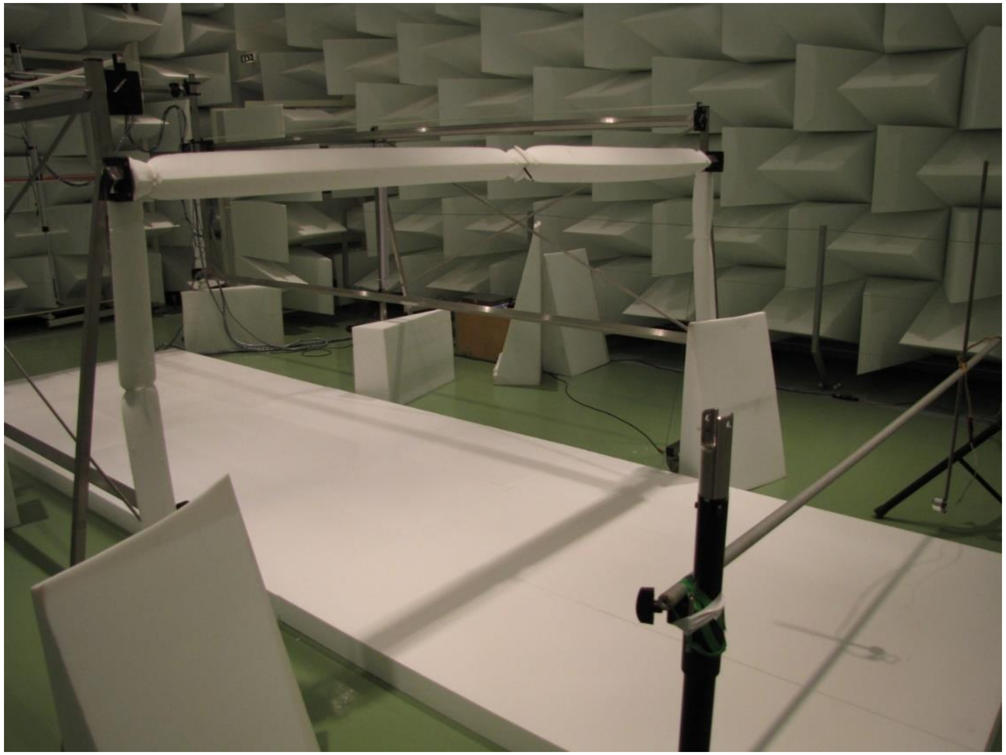
• 55m gaussian rough profile carved at scale 1/10 in two sets of polystirene boards (1 set = 9 boards, 2m x 0.6m)

• The two sets of rough boards are coated with epoxy resin. One is left uncovered to make it reflective, the other one is covered with 1mm layer of felt to make it absorbing.



II.3 – Flat surfaces

- Flat reflective and absorbing surfaces are also considered

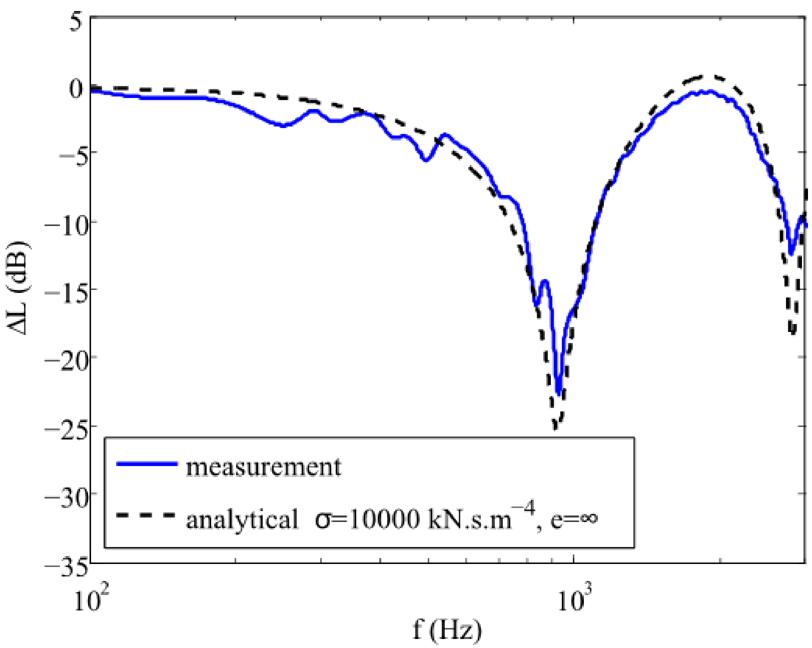


III. Measurements

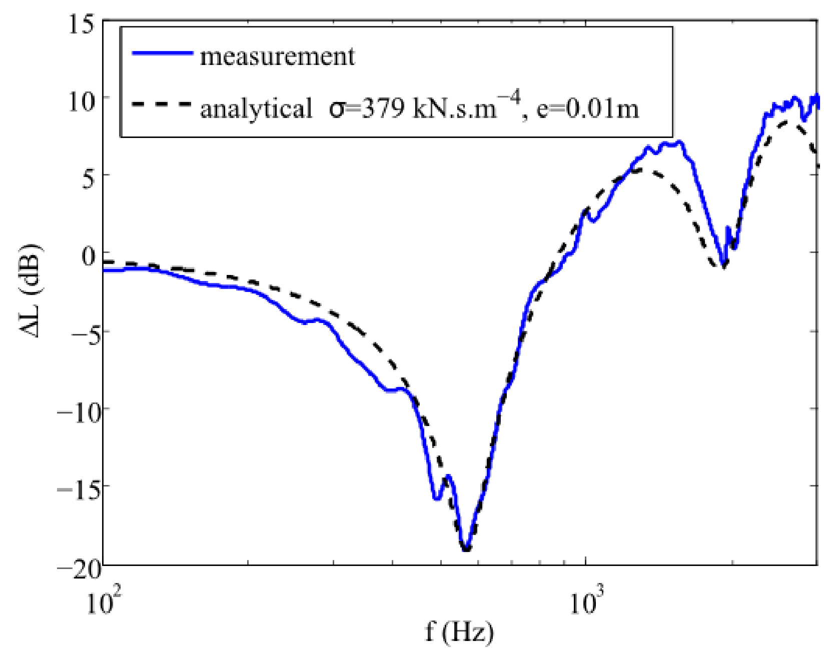
III.1 – Preliminary measurements

- The impedance of the flat surfaces is measured by a two-microphone technique, reproduced at scale 1/10
- Thickness is considered

Reflective flat surface

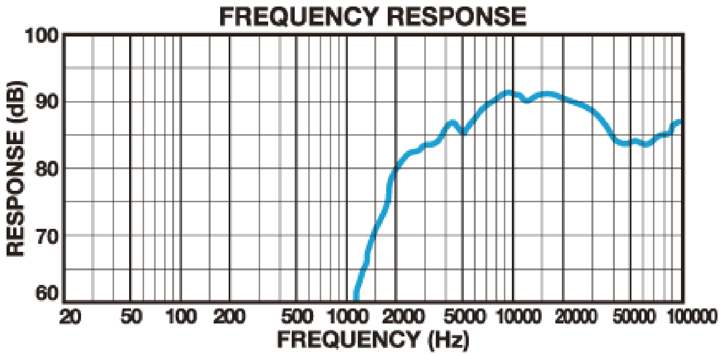


Absorbing flat surface



III.2 – Devices

- Source : Clarion SRH292HX tweeter



- Microphone : ¼” B&K 4961 multi-fields

Sensibility : 60 mV/Pa
Frenquency range : 5 Hz -20 kHz
Dynamic : 20 -130 dB

- White noise emitted, impulse responses obtained using B&K PULSE LabShop
- Frequency range of interest at full scale 200Hz-2000Hz

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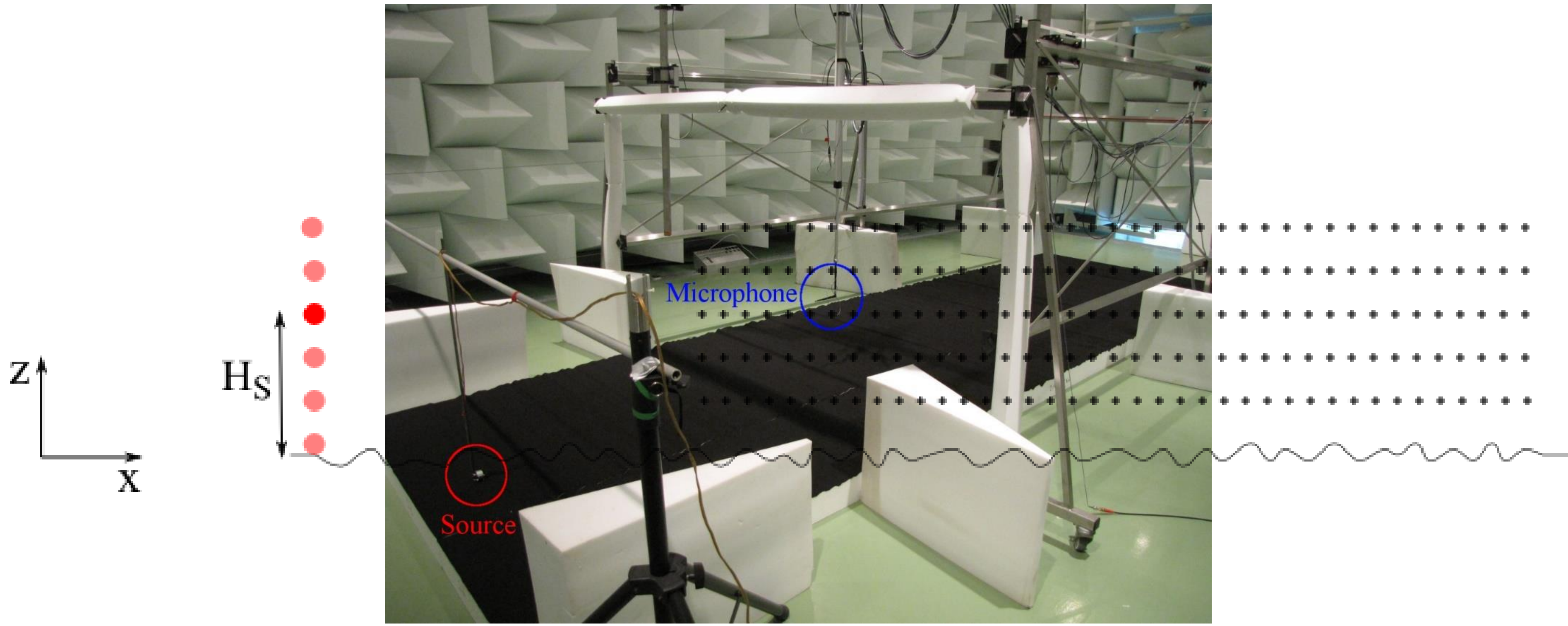
III.3 – Measurements configuration



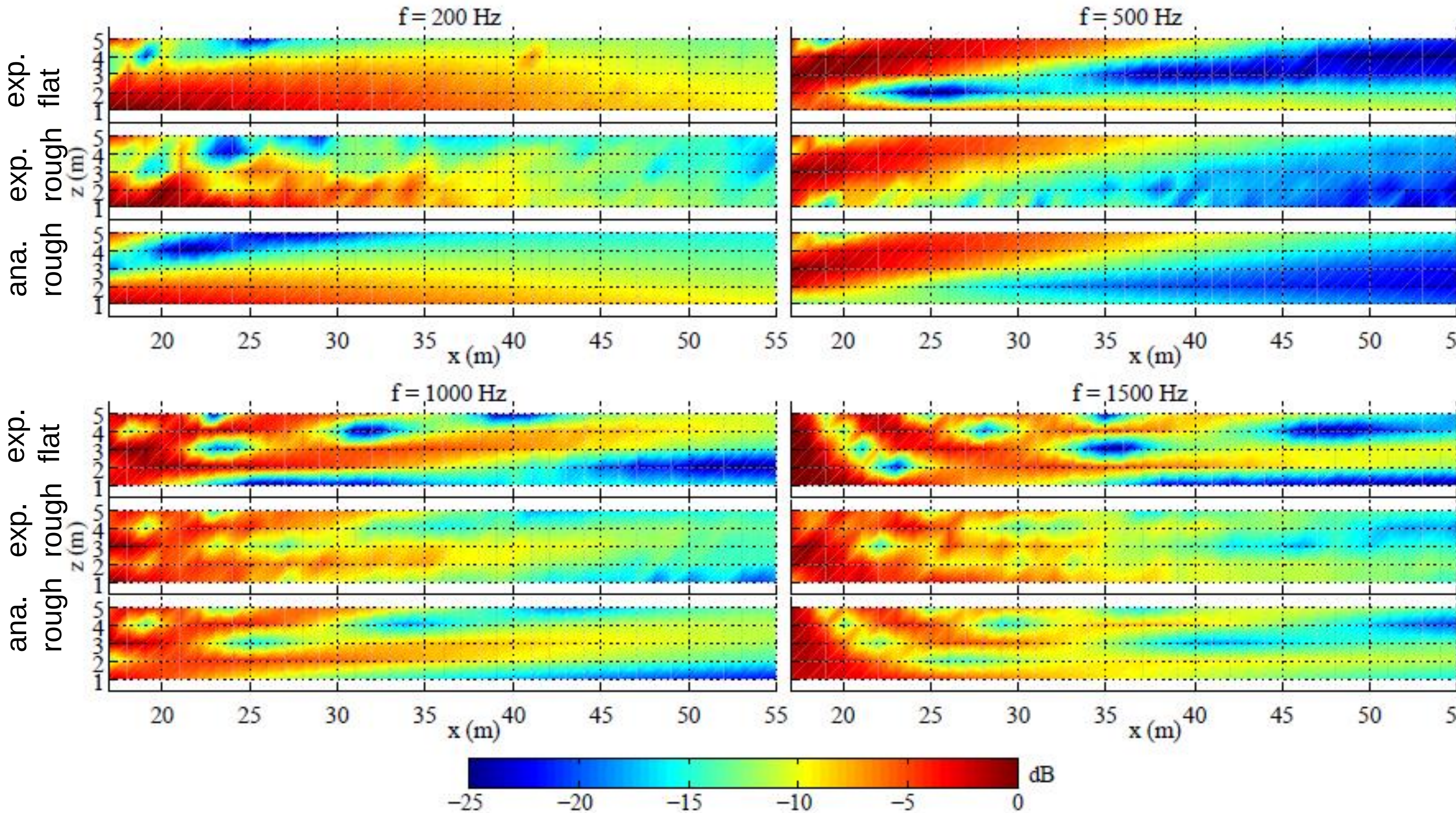
- 6 source heights H_S : 0.2, 1, 2, 3, 4, 5m
- The microphone position is controled by an automatic system
- 5 microphone heights H_R : 1, 2, 3, 4, 5m
- For each source height : d=17, 18, …54, 55m (all distances expressed at full scale)
- In total 1170 measurement points for each surfaces (reflecting and absorbing).

IV. Results in frequency-domain

IV.1 – Reflective surfaces

- H_S=2 m

SPL relative to free field at 1m



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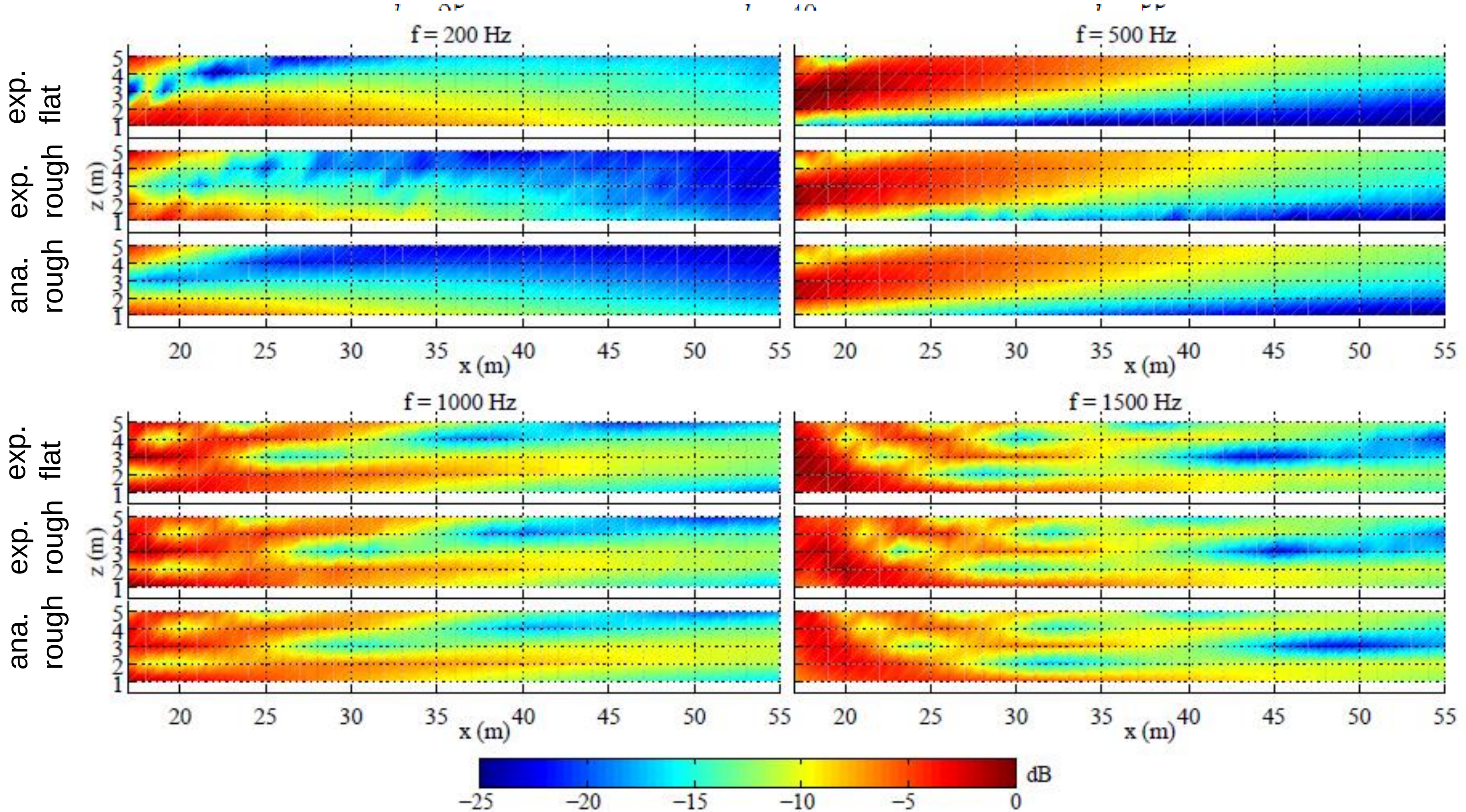
IV.2 – Absorbing surfaces

- Elevated source (H_S=2 m)



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- Natural grounds may exhibit a space variability of the impedance (parts of the ground more or less compact, or more or less moist)

- An *in-situ* measurement campaign of the impedance has been realized in order to:
  1. characterize the space variability of a natural ground
  2. obtain realistic input data to perform numerical simulation of propagation over a ground with a spatially variable impedance
- The measurements have been also performed at two different periods of the year, in order to assess the effects of the season on the impedance variability

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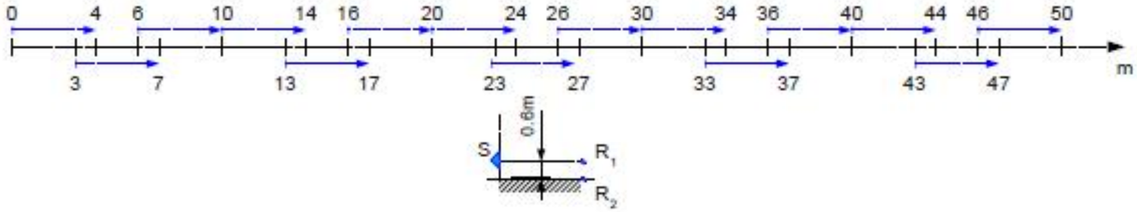
- A two-microphone technique† is applied to measure vertical attenuation spectra

- $H_S = 0.6$ m
- $H_{R1} = 0.6$ m
- $H_{R2} = 0$ m
- $d = 4$ m

- Measurements are made on two parallel 50 m lines (separated by 10 m), 15 measurements by line



- This experimental protocol is realized in *summer* and *winter*

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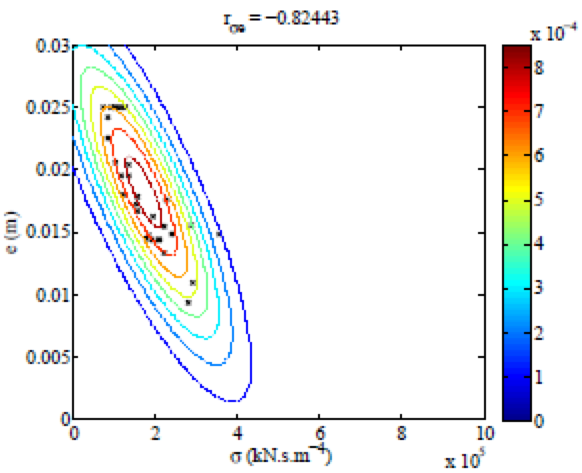
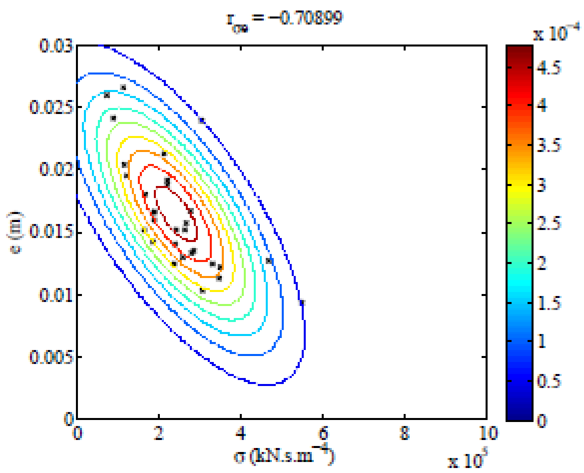
- The measured spectra are processed with a semi-automatic fitting procedure to estimate (σ, e) (Miki model) at each measurement point
- The space variability of the impedance parameters is statistically characterized

Summer



Winter



PhD Olivier Faure (2014)

- The measured spectra are processed with a semi-automatic fitting procedure to estimate (σ, e) (Miki model) at each measurement point
- The space variability of the impedance parameters is statistically characterized

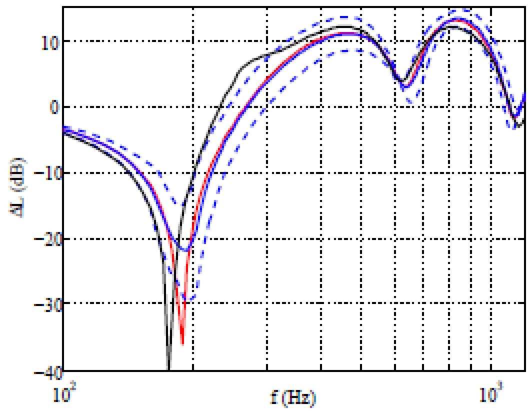
	Summer	*Winter*
$\overline{e}$ (cm)	1.8	1.6
s_e (cm)	0.46	0.45
$s_e/\overline{e}$	0.26	0.28
$\overline{\sigma}$ (kN.s.m^{-4})	172	243
s_σ (kN.s.m^{-4})	72	104
$s_\sigma/\overline{\sigma}$	0.41	0.43

$\Rightarrow$ The season only affects the mean values of the impedance and does not change the estimated relative space variability for this ground

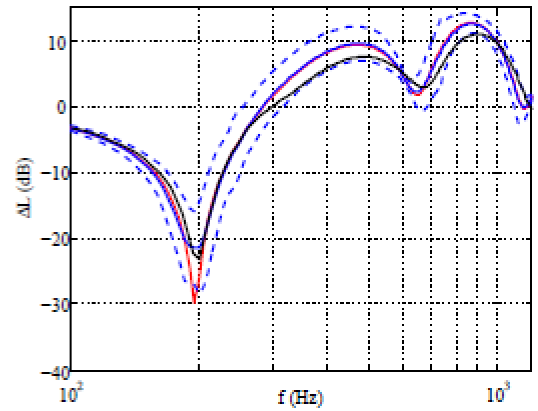
PhD Olivier Faure (2014)

- The numerical attenuation spectra for $d = 50$ m, $H_S = 4$ m, $H_{R1} = 4$ m, and $H_{R2} = 0.3$ m are compared to analytical results (WVDP formula) for homogenous grounds

Summer - Line 2



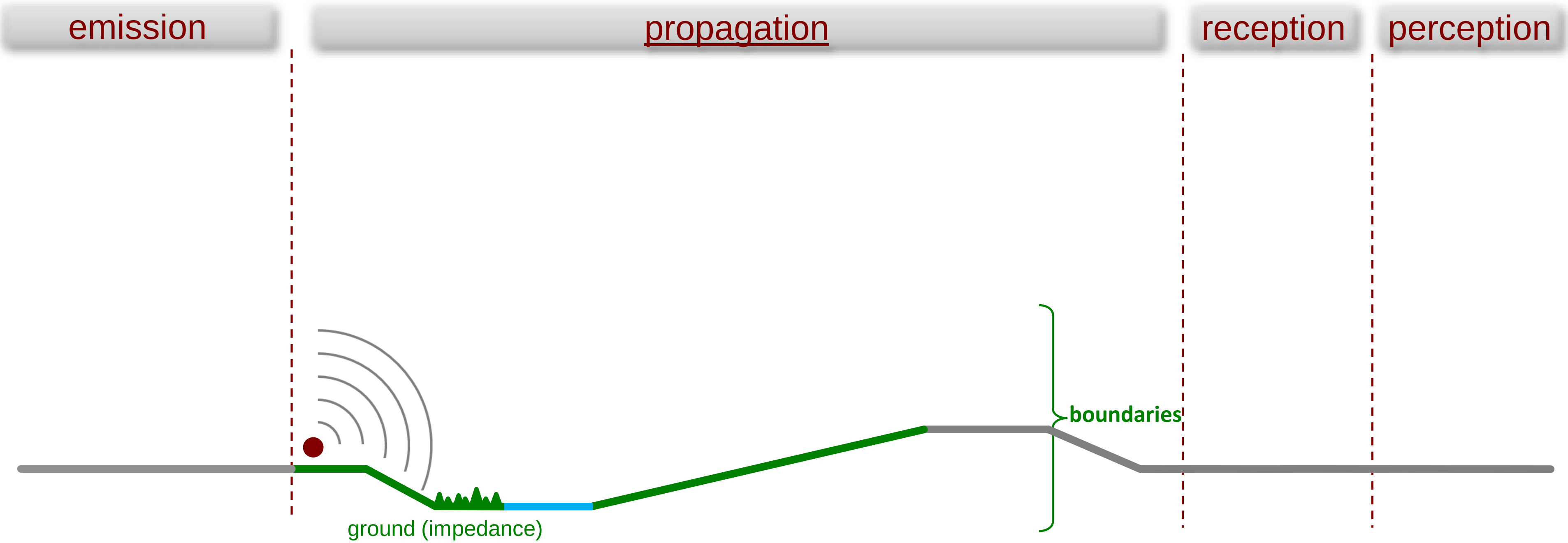
Winter - Line 2



(—) TLM results for $\sigma(x)$, $e(x)$; (—) Analytical results for $(\overline{\sigma}, \overline{e})$; (—) Mean values (- -) $\pm$ one std of analytical results for 100 random drawing of (σ, e)

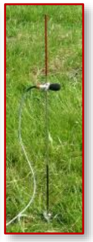
- The results can deviate from the homogenous case
  $\Rightarrow$ This shows the interest to take into account a space variability of the impedance for outdoor sound propagation predictions

MIAME Prototype for imped. meas.

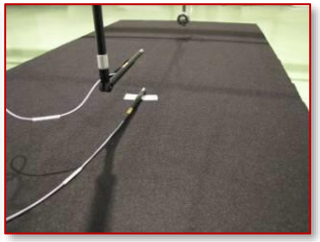


MIAME Prototype for imped. meas.

- System for measuring, post-processing and analizing ground characteristics (impedance)





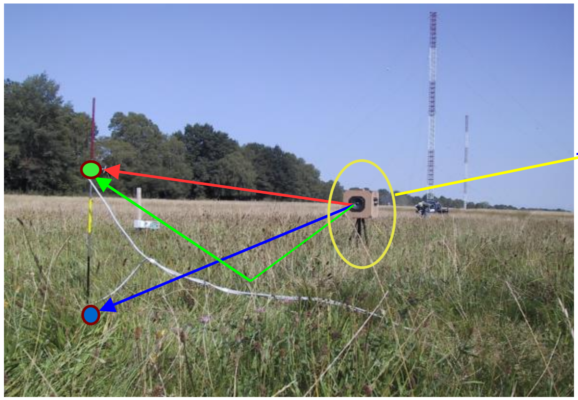


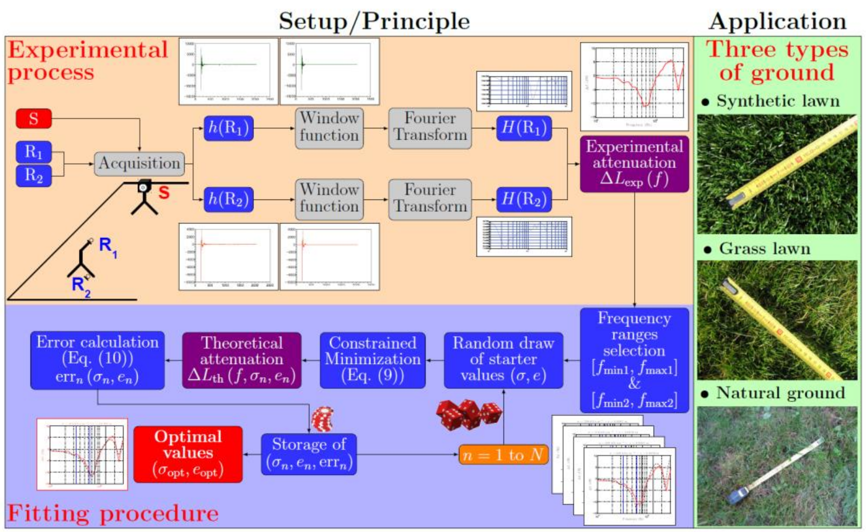
- Airflow resistivity: Typical values for current grounds

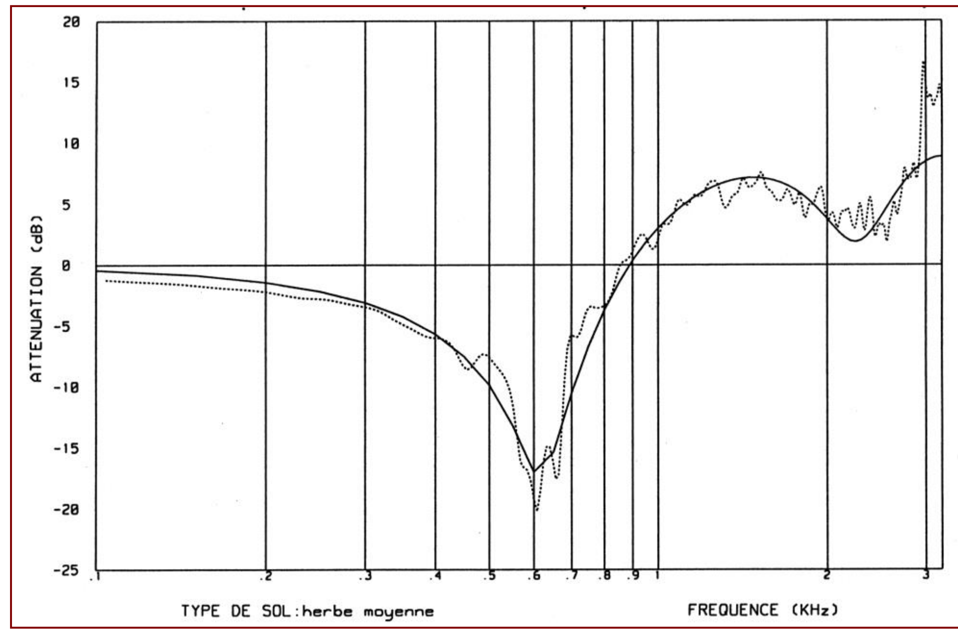
IFSTTAR Cerema

Typologie de sol	Résistance spécifique au passage de l'air (en unités cgs ou $kNsm^{-4}$)	Propriétés acoustiques
Neige fraîche	10 à 50	Très absorbant
Sous-bois sec (feuilles, épines)	20 à 100	
Prairie, terre fraîchement labourée	100 à 500	Absorbant
Gazon, terrain de stade	300 à 1000	
Terre compactée, terre roulée et déchaumée	1 000 à 5 000	
Revêtement routier (hors chaussée poreuse)	50 000 à 100 000	Réfléchissant
Eau, glace, béton lisse et peint	> 100 000	Très réfléchissant

MIAME Prototype for imped. meas.







9-12 AUGUST 2015
inter.noise 2015
SAN FRANCISCO, CALIFORNIA USA

Uncertainties of an *in situ* method for measuring ground acoustic impedance

D. Ecotière, Ph. Glé, R. Boittin, H.Lefèvre, D. Lunain

CEREMA, France

B. Gauvreau

IFSTTAR, France

Introduction

- Ground effect on sound propagation

  [Embleton, 1996] [Berengier,2003] [Attenborough, 2007]

- Measurement of outdoor ground impedance (input parameters)

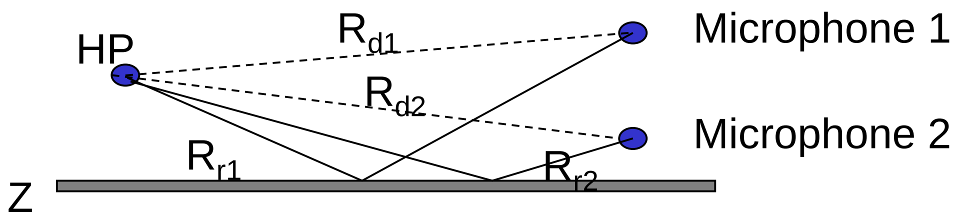
- Need for an *in situ* method and for an automated estimation procedure

>> Uncertainties of the procedure ?

The measurement method

2-microphones method

- Principle [Hess,1990] [Sabatier,1990] [Sabatier,1993][**Guillaume,2015**]

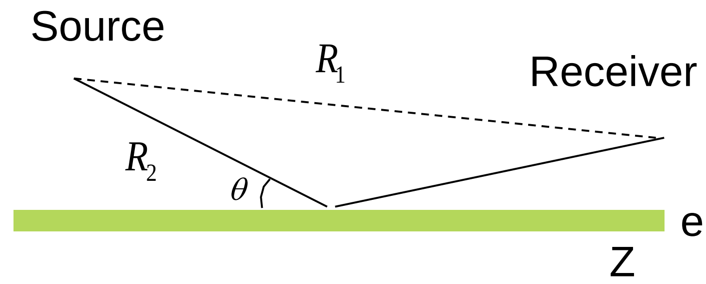


- Measurement of the spectrum transfer function between 2 points

$$\Delta L = 10\log_{10}\left|\frac{p_1}{p_2}\right|^2$$

- Estimation of the Z parameters by fitting calc/measured of *ΔL*

Theory



- Ground effect

  - Propagation model [Rudnick, 1947]

$$p_R / S = \frac{e^{ikR_1}}{R_1} + Q\frac{e^{ikR_2}}{R_2}$$

  - Spherical reflexion coefficient :

$$Q = R_p + (1 - R_p)F(w)$$

  - Plane wave reflexion coefficient :

$$R_p = \frac{Z\sin\theta - 1}{Z\sin\theta + 1}$$

  - Faadeva function :

$$F(w) = 1 + 2j\,w\,e^{-w^2}\int_{-jw}^{\infty} e^{-u^2}\,du$$

with $$w^2 = \frac{1}{2} j k R_2 \left(\sin\theta + \frac{1}{Z}\right)^2$$

Theory

- Models of acoustic impedance

  - Thickness correction $Z_c = Z \coth(-jke)$

  - Miki model [Miki, 1990]

$$0.01 < \frac{f}{\sigma} < 1.00$$

$$\begin{cases} Zc = Z_0 \left(1 + 5.5 \left(\frac{f}{\sigma} \right)^{-0.632} + j8.43 \left(\frac{f}{\sigma} \right)^{-0.632} \right) \\ k = k_0 \left(1 + 7.81 \left(\frac{f}{\sigma} \right)^{-0.618} + j11.41 \left(\frac{f}{\sigma} \right)^{-0.618} \right) \end{cases}$$

➔ 2 unknown parameters :
σ (air flow resistivity)
e (thickness)

Theory

- Models of acoustic impedance

  - Thickness correction $Z_c = Z \coth(-jke)$

  - Zwikker and Kosten model [Zwikker and Kosten, 1949] $Z = \sqrt{\rho K}$

$$\rho = \frac{\alpha_\infty \rho_0}{\phi}\left[1 - \frac{2}{\lambda\sqrt{-j}} \frac{J_1(\lambda\sqrt{-j})}{J_0(\lambda\sqrt{-j})}\right]^{-1} \qquad K = \frac{\gamma P_0}{\phi}\left[1 + \frac{2(\gamma-1)}{\sqrt{\Pr}\lambda\sqrt{-j}} \frac{J_1(\sqrt{\Pr}\lambda\sqrt{-j})}{J_0(\sqrt{\Pr}\lambda\sqrt{-j})}\right]^{-1} \qquad \lambda = \sqrt{\frac{8\omega\rho_0\alpha_\infty}{10^3\sigma\phi}}$$

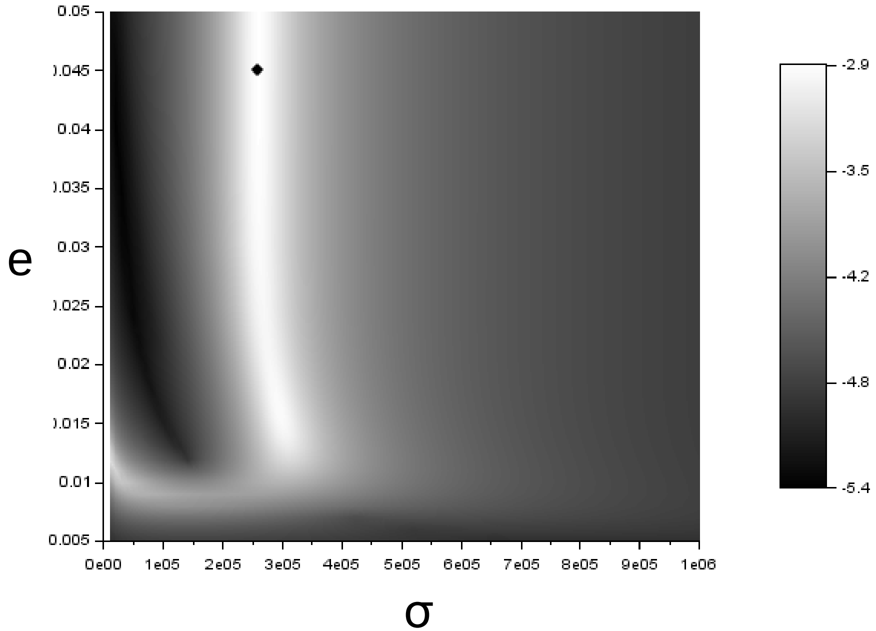
➔ 4 unknown parameters :

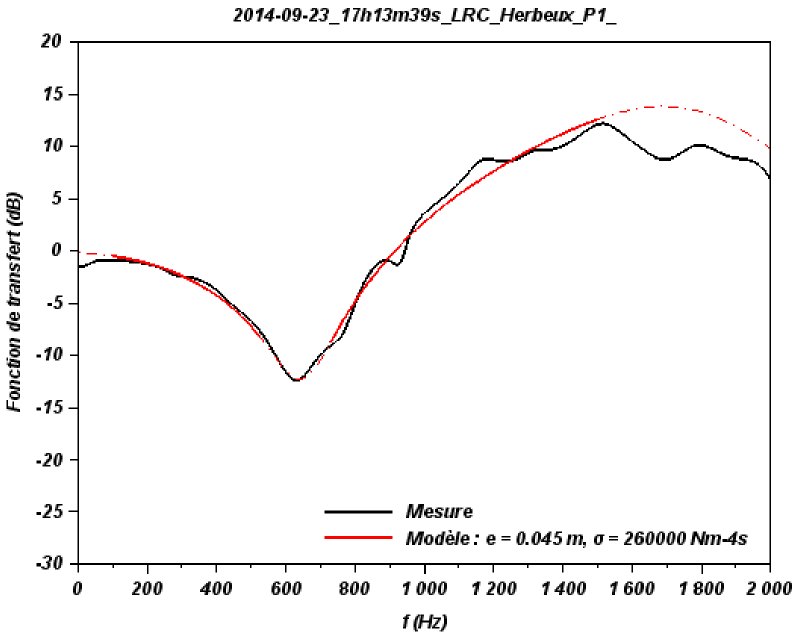
σ (air flow resistivity)
ϕ (open porosity)
α (tortuosity)
e (thickness)

Theory

- Inverse problem : minimization of a cost function by an exhaustive search

$$F(Z) = \sum_{f\min}^{f\max} \left| \Delta L_{calculated}(f,Z) - \Delta L_{measured}(f,Z) \right|^2$$



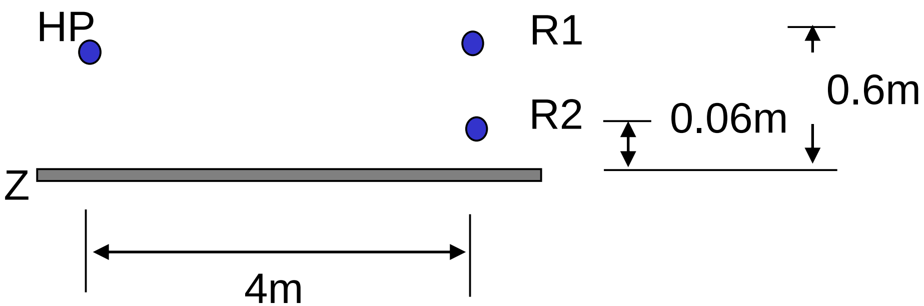


Uncertainties estimations

Uncertainties estimations

- Experimental apparatus
  - All in one autonomous apparatus
  - Scilab-based software
  - In situ measurement + in situ parameters estimation

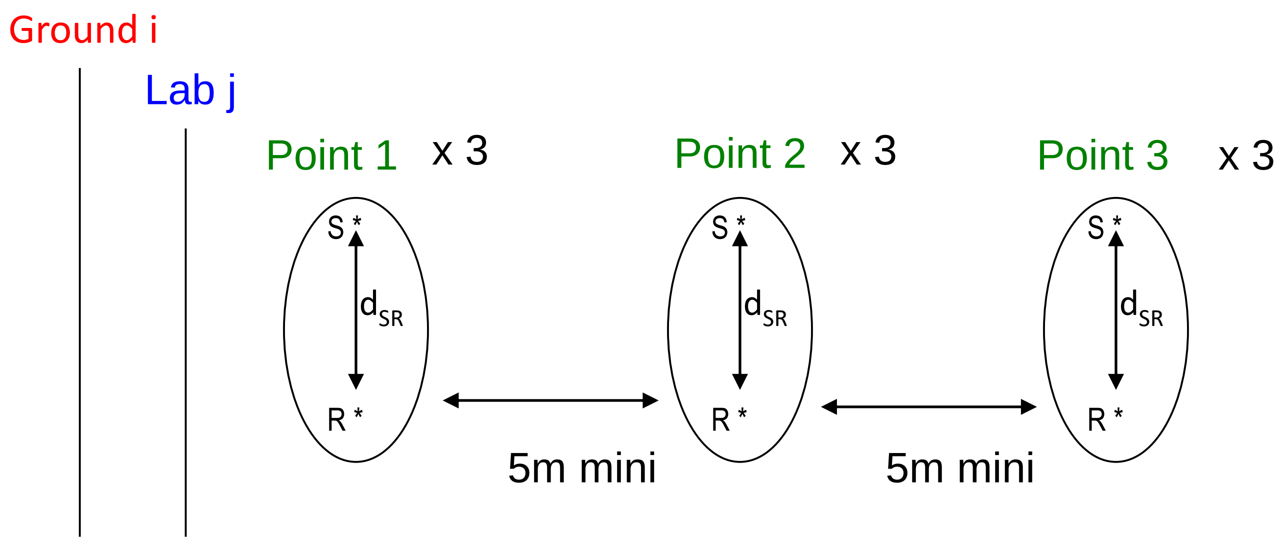
- Experimental set-up



Uncertainties estimations

- Round robin test : experimental protocol
  - 5 laboratories, whith the same kind of exp. device
  - 3 repetitions / point

  - 5 outdoor grounds
  - 3 points / ground

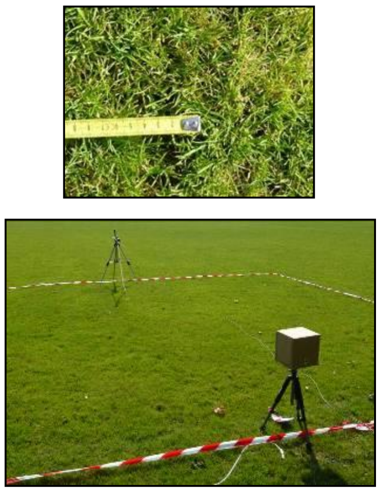


Uncertainties estimations

- Round Robin test : experimental protocol

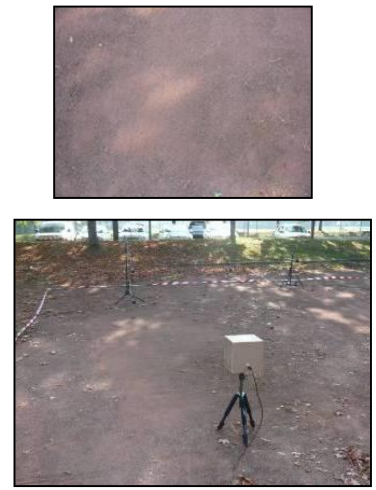
  - 5 kinds of outdoor grounds :

Synthetic lawn

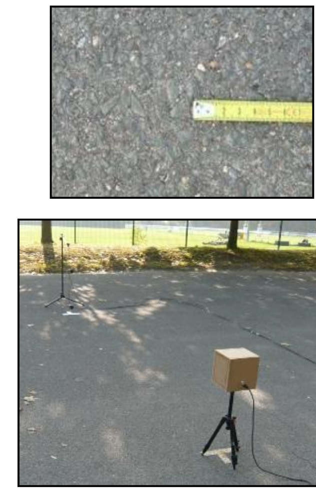


Natural lawn

Natural grass



Compacted ground



Non porous asphalt

B. Gauvreau, D. Écotière, P. Glé, R. Boittin,
H. Lefèvre et D. Lunain tiennent à remercier…

… tous les acteurs ayant contribué au développement et aux campagnes de mesures :

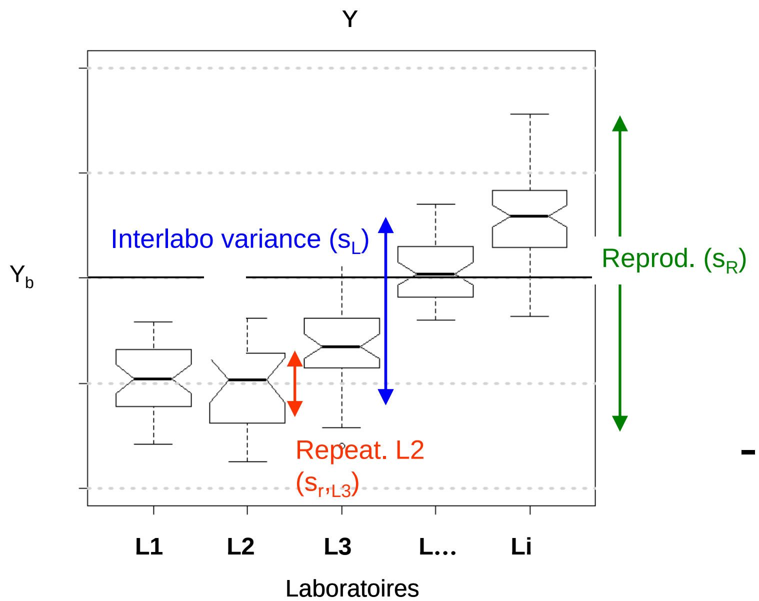
> M. Bérengier
> E. Consolat
> J.-L. Derbez
> G. Dutilleux
> V. Gary
> P. L'Hermite
> L. Ségaud
> Mairie de Blois

Uncertainties estimations

- Round Robin test : uncertainties estimations

  - ISO 5725-2 : round robin test, interlaboratory measurements

  - Uncertainties : reproducibility and repeatability



- Repeatability (s_r) : mean dispersion inside labs

- Interlabo var (s_L) : dispersion between labs

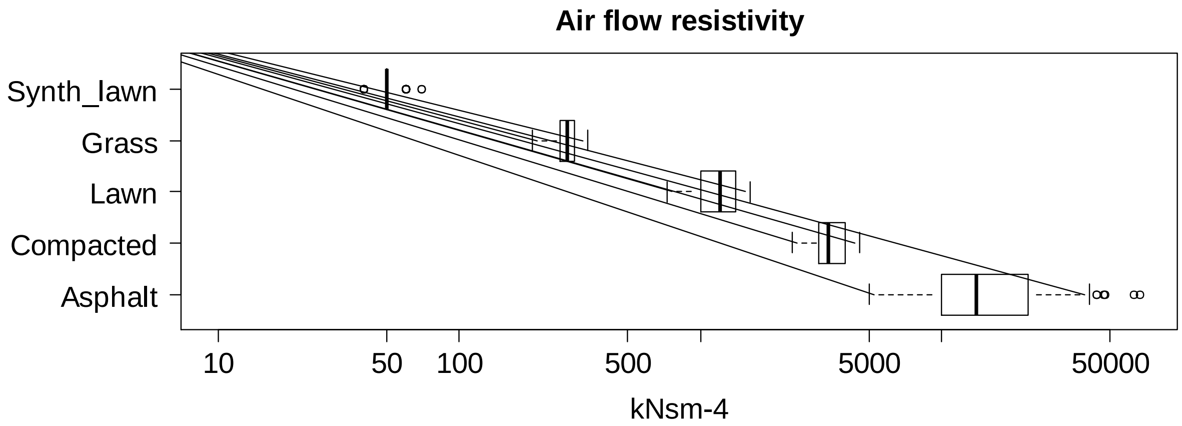
- Reproducibility : $s_R^2 = s_L^2 + s_r^2$

- Uncertainties : $Y = Y_b \pm k s_R \;\; (k = 2)$

Results

Air flow resistivity uncertainties

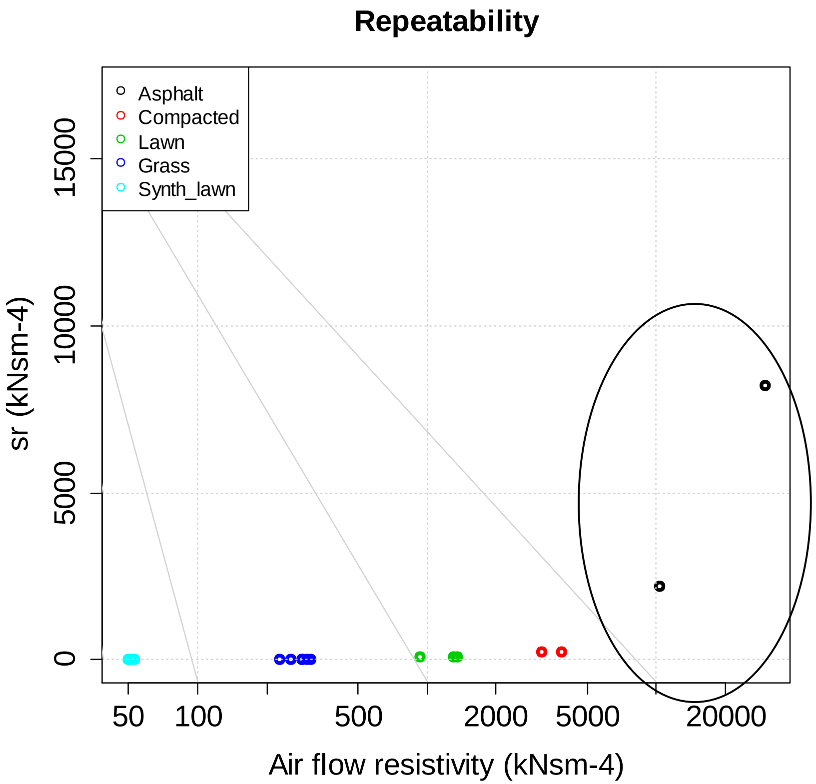
- Reprod. and repeat. *vs* ground type

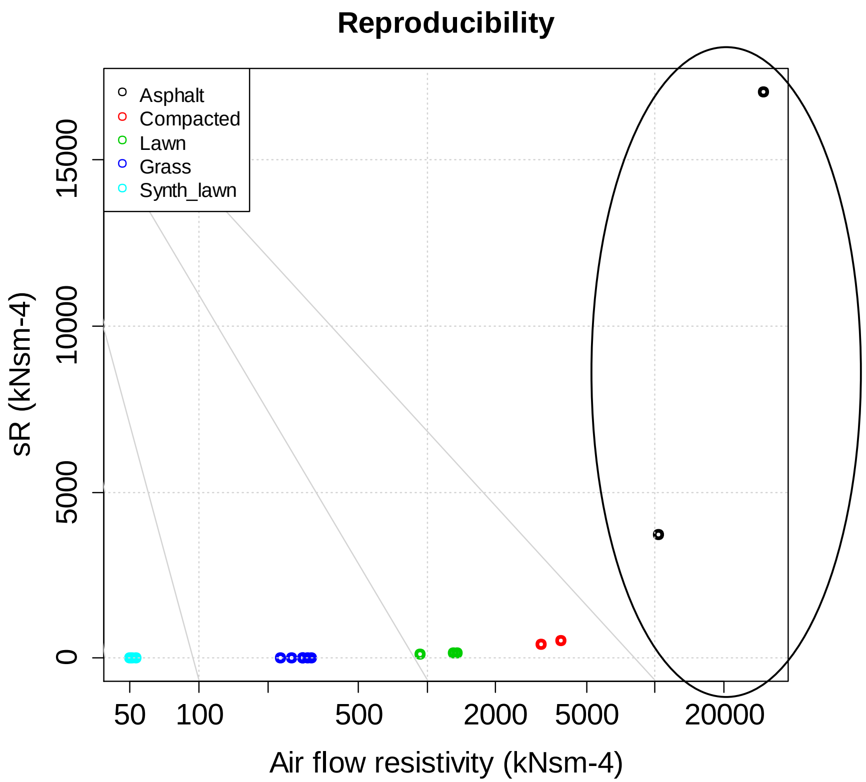


Air flow resistivity (kNsm^{-4})	Mean	s_R (reprod.)	S_r (repeat.)	s_L (interlab.)
Non porous Asphalt	**19 609**	**15 070**	**13 065**	**7 510**
Compacted ground	**3 519**	**567**	**512**	**245**
Natural lawn	**1 154**	**248**	**217**	**119**
Grass	**277**	**34**	**34**	**6**
Synthetic lawn	**51**	**7**	**5**	**5**

Air flow resistivity uncertainties

- Results : reprod. and repeat. *vs* air flow resistivity

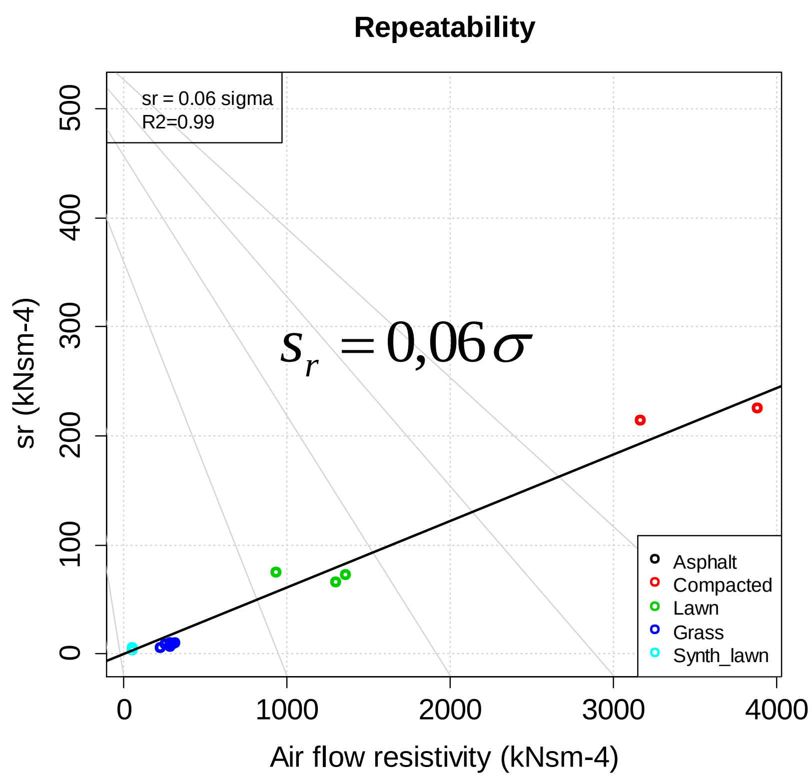


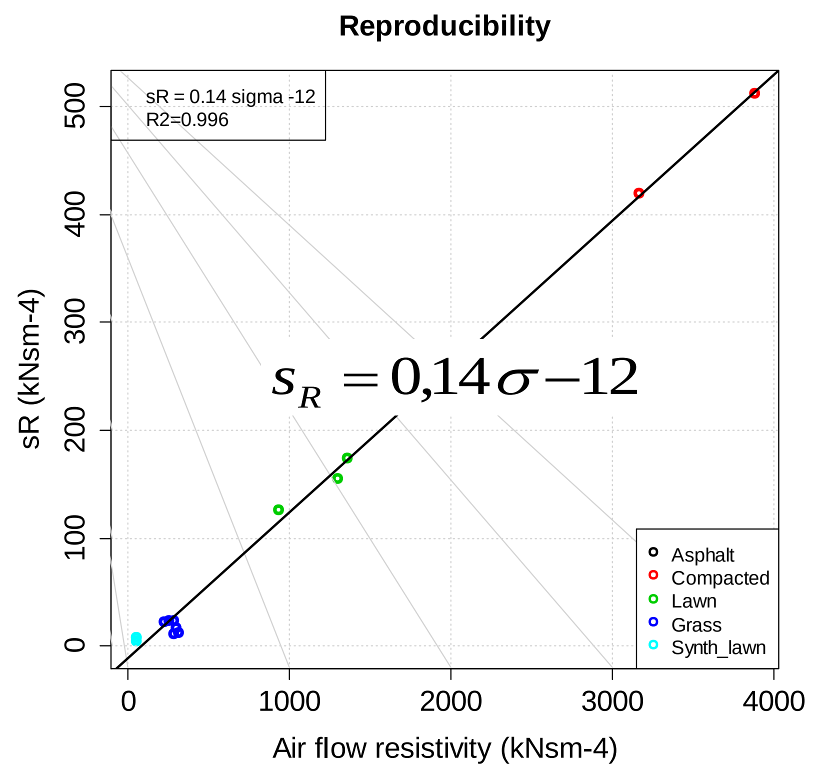


$\sigma > 5\ 000$ kN.s.m^{-4} : high uncertainties

Air flow resistivity uncertainties

- Results : reprod. and repeat. *vs* air flow resistivity

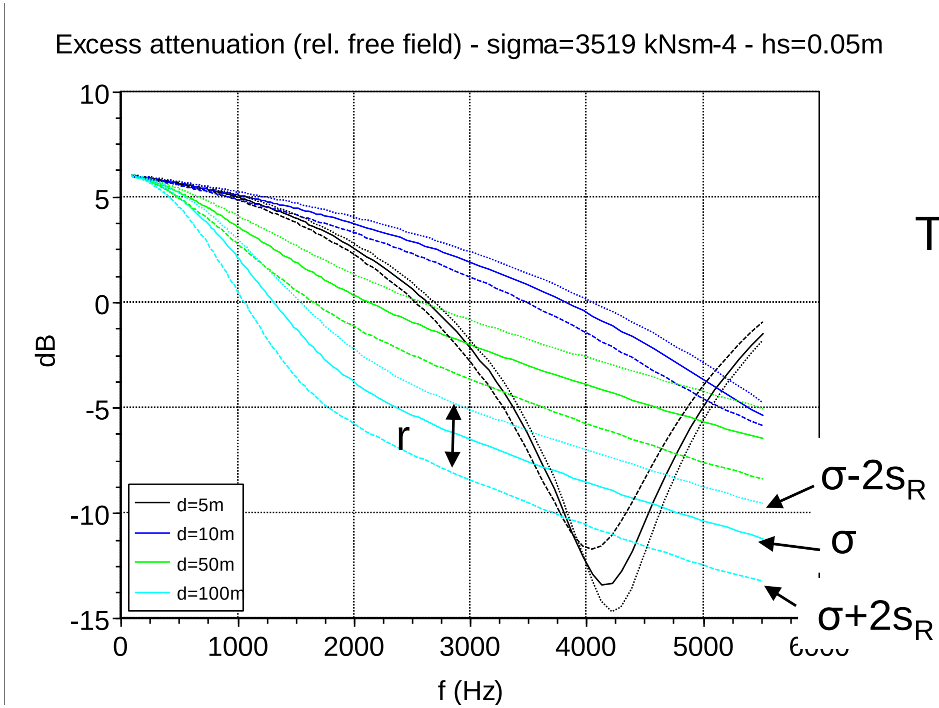




σ < 5 000 kN.s.m^{-4} : uncertainties < 6% (resp. 14%)

Impedance induced uncertainties on SPL

- Uncertainties on sound level prediction



Type-uncertainty of sound level prediction:

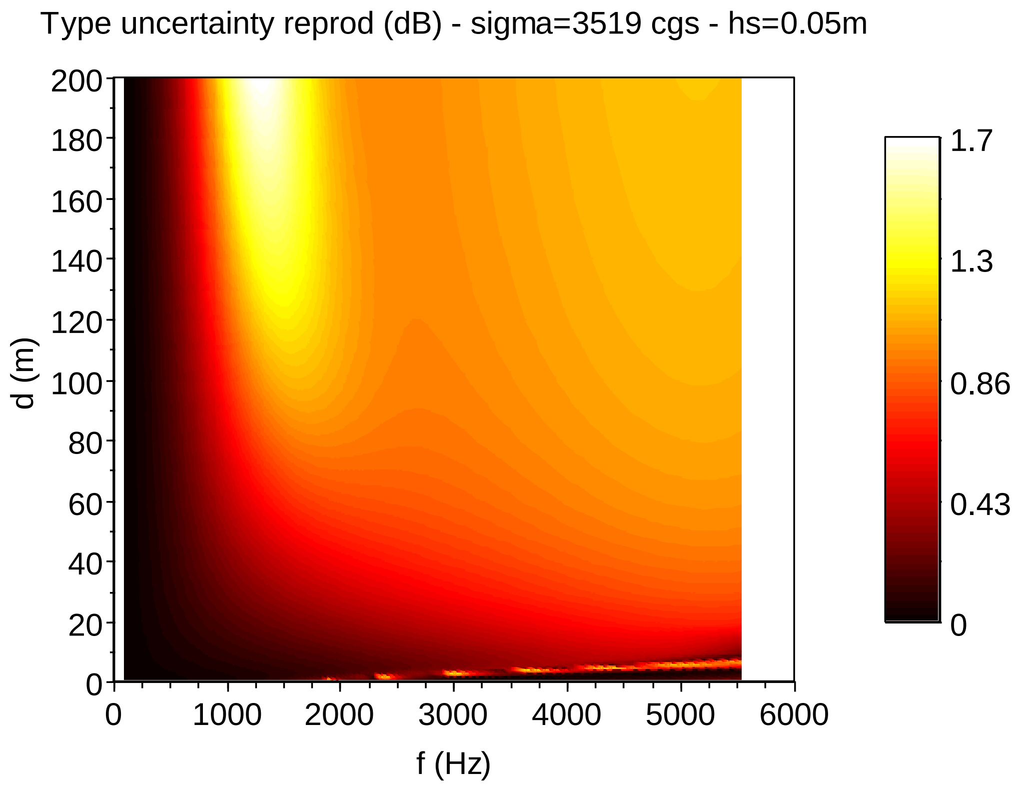
$$s = \frac{r}{2\sqrt{3}}$$

(assumption of uniform distribution)

Impedance induced uncertainties on SPL

- Uncertainties on sound level estimation

Example for hr=2m, d=1:200m and f=100:5000 Hz



Impedance induced uncertainties on SPL

- Uncertainties on sound level estimation

Maximum type-uncertainty of SPL 1/3rd octave band
(under **reproducibility** conditions)

example for hr=2m, d=1:200m and f=100:5000 Hz

		hs=0.05 m	hs=1 m	hs=3 m	hs=10 m
	σ =3 519	**1,7 dB**	**2,1 dB**	**1,2 dB**	**1 dB**
	σ = 1 154	**2,1 dB**	**2,3 dB**	**1,6 dB**	**1 dB**
	σ = 277	**2,6 dB**	**2,9 dB**	**2,2 dB**	**1 dB**

Type-uncertainty (1/3rd oct bands) <3 dB

Impedance induced uncertainties on SPL

- Uncertainties on sound level estimation

Maximum type-uncertainty of SPL 1/3rd octave band
(under **repeatability** conditions):

example for hr=2m, d=1:200m and f=100:5000 Hz



	hs=0.05 m	hs=1 m	hs=3 m	hs=10 m
σ =3 519	**0,7**	**1**	**0,6**	**0,6**
σ = 1 154	**1**	**1,2**	**0,8**	**0,6**
σ = 277	**1,2**	**1,3**	**1,3**	**0,6**

Type-uncertainty (1/3rd oct bands) <1,3 dB

Conclusions

- Development of an autonomous in situ apparatus
- Uncertainties of the 2 microphones method for air flow resistivity
  - $\sigma > 5\,000$ kN.s.m^{-4} : high uncertainties
  - $\sigma < 5\,000$ kN.s.m^{-4} : $s_R<15\%$ and $s_r<6\%$

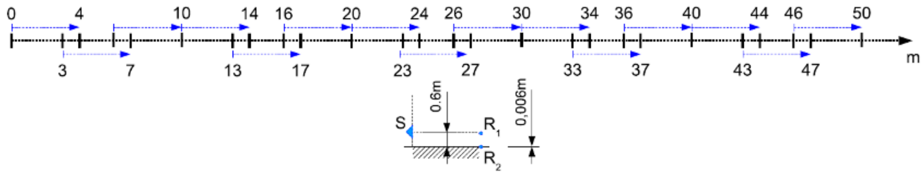
  ➔ the method is well adapted to non reflective outdoor material
- Impact on the uncertainties of sound level estimations :
  - Type-uncertainty (1/3rd oct bands) <3 dB (reprod.) or <1,3 dB (repeat.)
  - Note : uncertainties are probably overestimated in this study

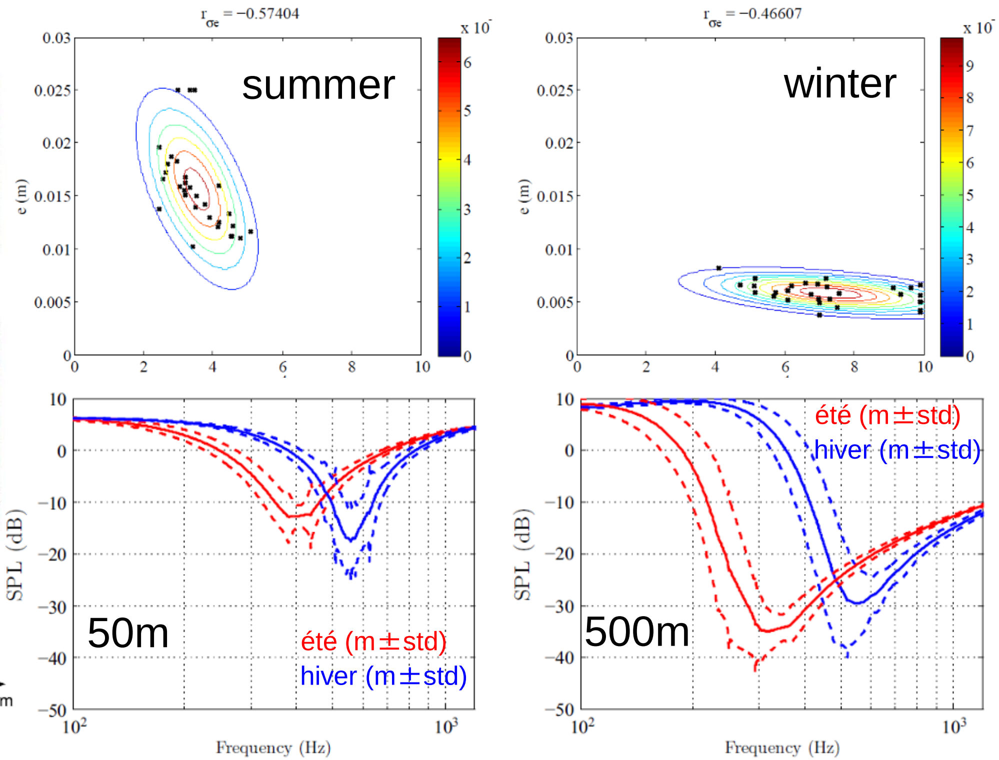
MIAME Prototype for imped. meas.

- Space AND time variability of parameters σ and e

(a) Synthetic lawn (b) Grass lawn (c) Natural ground

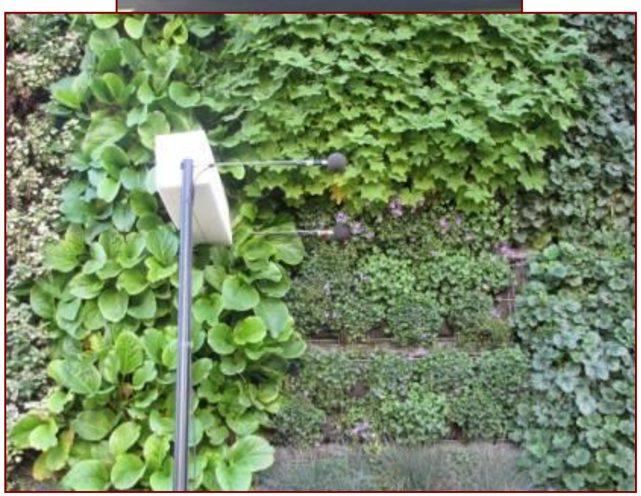
(d) Synthetic lawn (e) Grass lawn (f) Natural ground

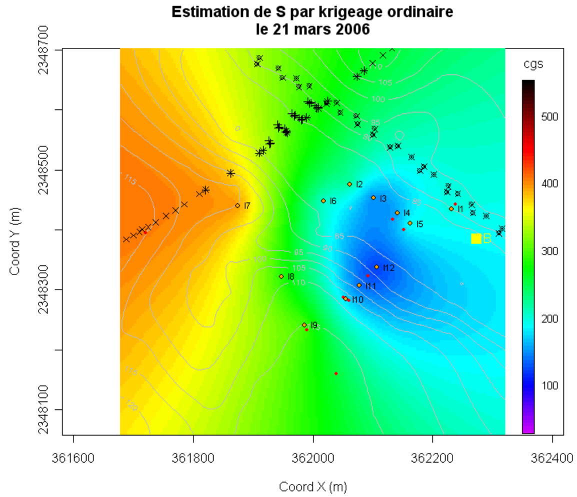


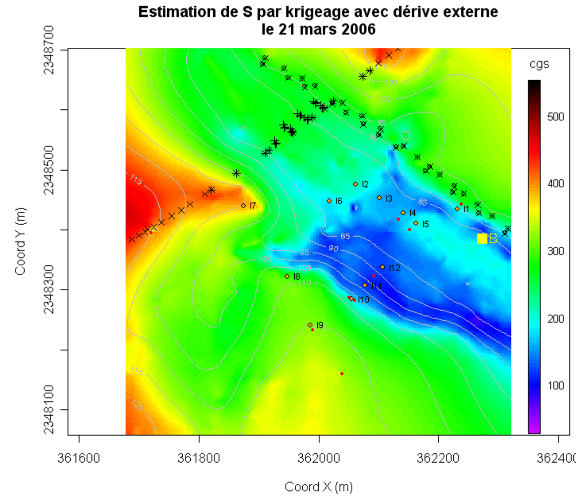


MIAME Prototype for imped. meas.

- Applications
  - For engineering and research (laboratory, industry, university, etc.)
  - Space AND time variability of parameters σ, e… and others (porosity, tortuosity, etc.)







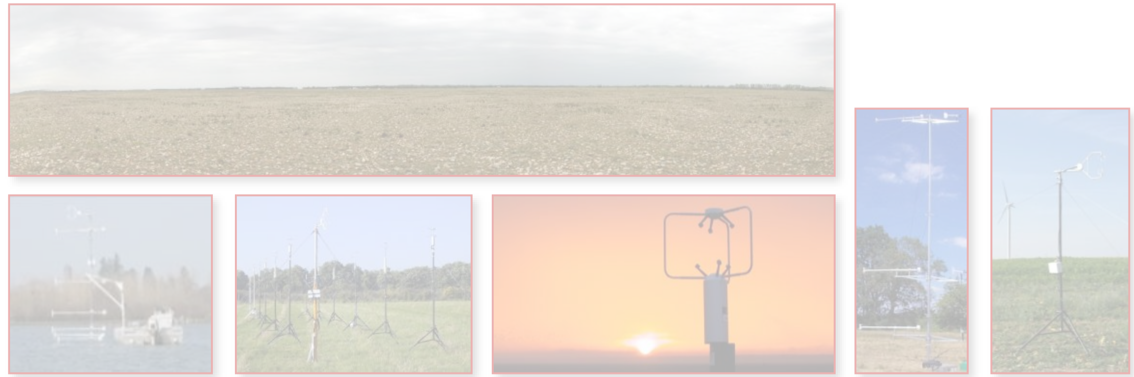
Contents

> **Foreword**

- Noise emission
- *Noise propagation : influence of boundaries characteristics and medium (atmosphere / micrometeo) conditions*
- Noise reception/perception

> **Examples in *open field*** (without obstacles, flat or complex topography)

- Laon_1999
- Harmonoise_2002-2004
- Lannemezan_2005
- Sonic_2007
- LTMS_2002-2007
- Fouché_2013
- Ifsttar_2011
- PhD Thesis O. Faure (2014)
- PhD Thesis B. Kayser (2017) >> LRSP
- MIAME prototype (impedance measurement)

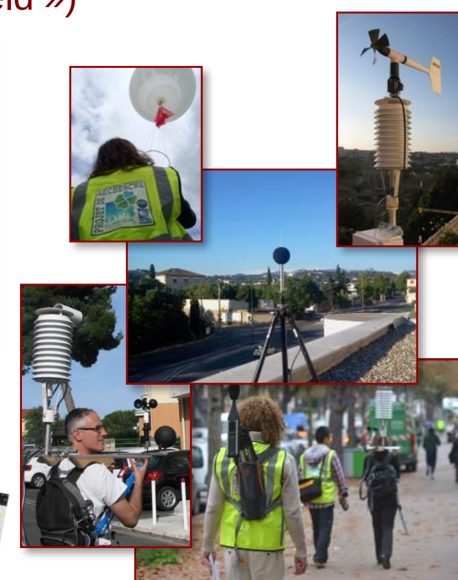


> **Examples in *urban medium*** (multiple sound sources + obstacles >> « diffuse field »)

- Tours_2002
- EM2PAU_2012
- VegDUD_2014
- EUREQUA_2016
- CENSE_2018



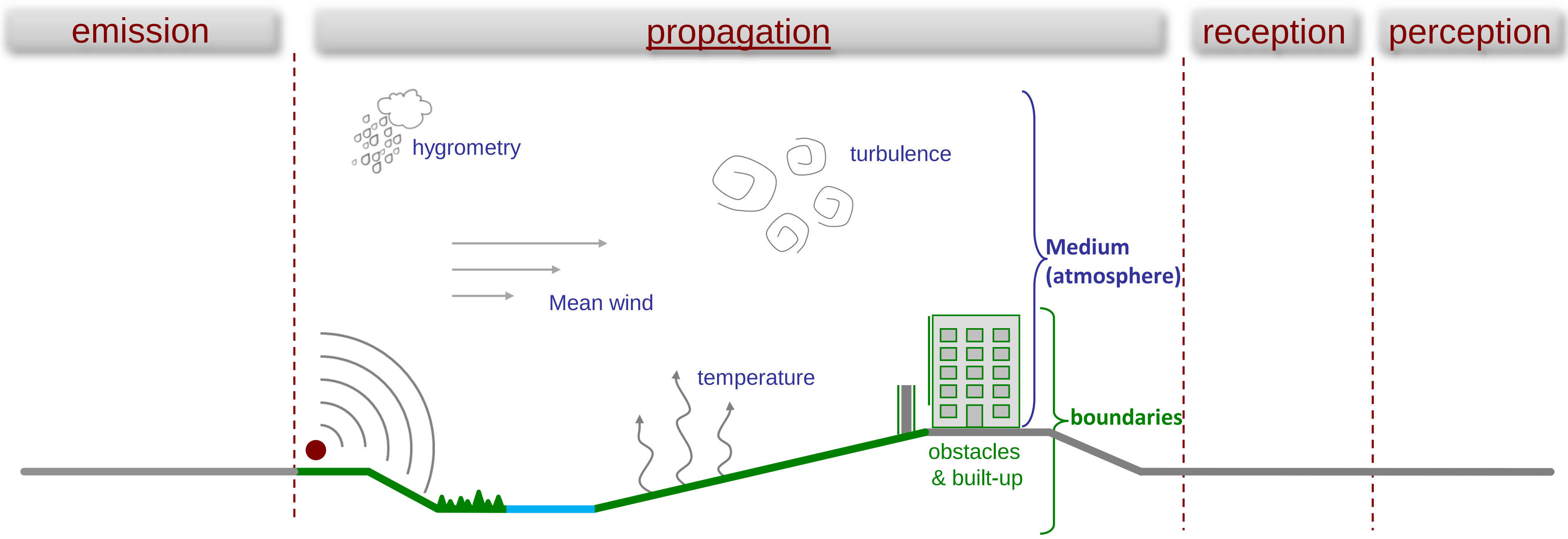




> **Conclusion and outlooks**

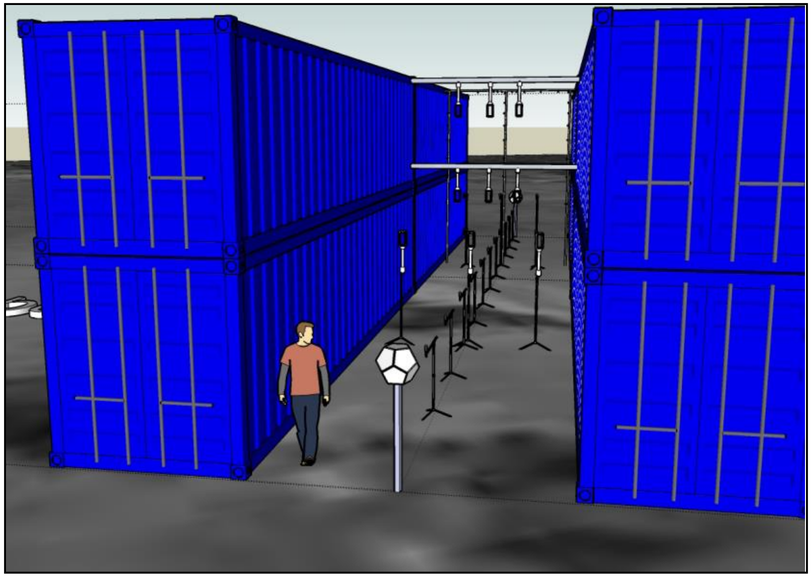
- Variability (deterministic) + uncertainty (stochastic)
- SPL dispersion in space
- SPL dispersion in time
- Other indicators (EDT, TR, etc.)
- Influent parameters (observables) for outdoor sound propagation
- Input data for numerical predictions
- >> D. Écotière lesson on "Uncertainties and variability"…

EM2PAU_2012


emission
propagation
reception
perception
hygrometry
turbulence
Mean wind
temperature
Medium
(atmosphere)
boundaries
obstacles
& built-up

EM2PAU_2012

EM2PAU_2012



EM2PAU_2012

Experimental site meteorological instrumentation (1/2)

Outside the scale model:

- 2 meteorological masts (10 m high)
  - 1[st] mast : 2 ultrasonic anemometers 3D Young 81000 (sampling 20 Hz) at 3 m high (with Temperature and Relative Humidity ventilated probe) and at 10 m high
  - 2[nd] mast : 1 ultrasonic anemometer Metek USA-1 at 10 m high

Fig.: Meteorological masts around the scale model.

Inside the street:

- 1[st] cross-section (at 6 m from the street extremity)
  - 3 ultrasonic anemometers 3D Young 81000 (sampling 20 Hz) at 3 m high
- 2[nd] cross-section (centrally located in the street):
  - 6 ultrasonic anemometers Gill Windmaster at 2 m and at 4 m high
  - 48 thermocouples

(a) 1[st] cross-section (b) 2[nd] cross-section

Fig.: Anemometers distribution in the street scale.

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EM2PAU_2012

Experimental site acoustic instrumentation

Sound emission:

- omnidirectional source B&K

Acquisition:

- Pulse™ system B&K
- 18 ½-inch free-field microphones:
  - 11 microphones along the street axis
  - 6 microphones across the central section
  - 2 microphones outside the street

Fig.: Acoustic instrumentation photo.

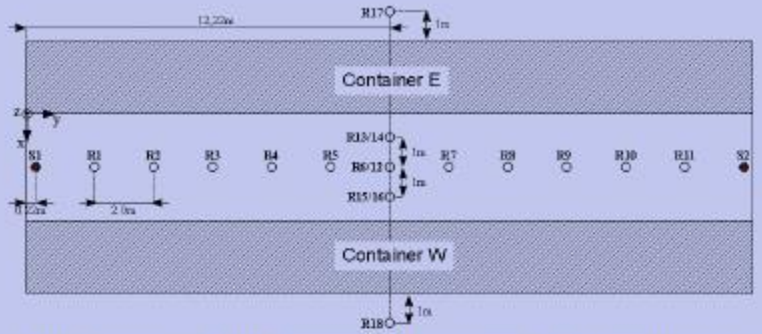
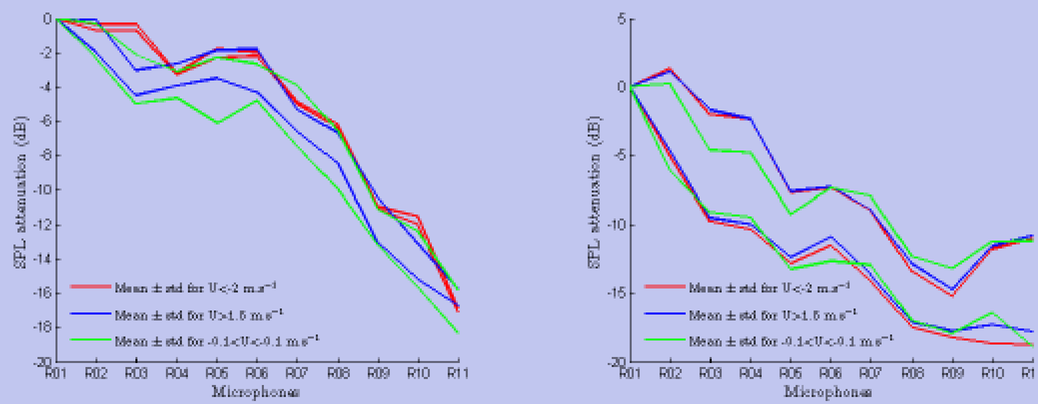


Fig.: Source and microphones locations in the street scale.

Acoustic data processing

- 1-minute duration impulse responses (IR) measurements (IR duration: 250 ms, 110 spectrum linear averages)
- steady-state sound levels computation from the IR per 1/3 octave band
- no compensation of the excess attenuation due to atmospheric absorption in the scale model compared with the full-scale street

Sound attenuations along the street axis



(a) $f_c = 100$ Hz (b) $f_c = 1000$ Hz

Fig.: Sound levels along the street scale axis relative to sound pressure level at microphone R01 for upwind, downwind and homogeneous conditions at the 1/3 octave bands of central frequencies (a) 100 Hz and (b) 1000 Hz.

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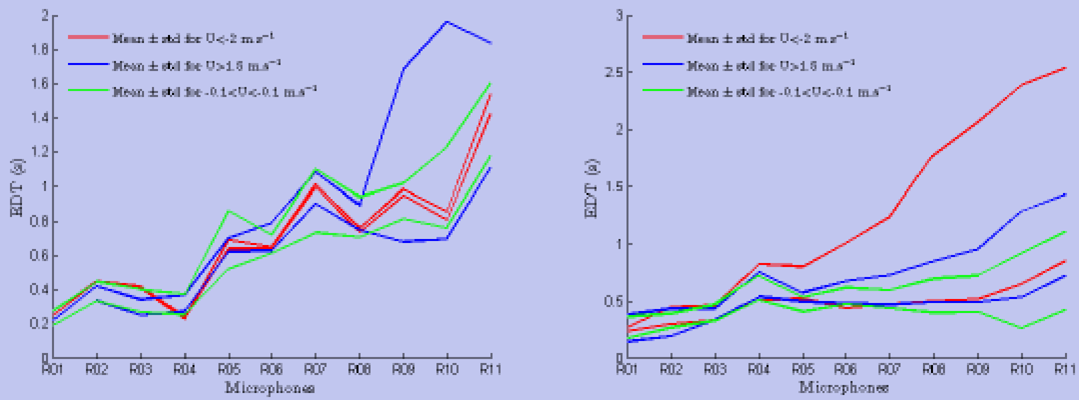
EM2PAU_2012

Sound decays along the street axis



(a) f_c = 100 Hz (b) f_c = 1000 Hz

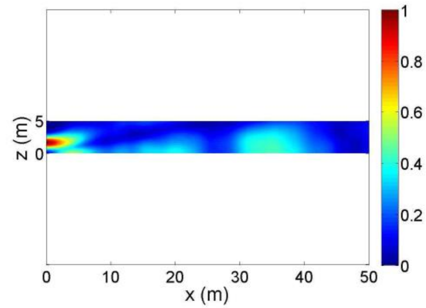
Fig.: EDT along the street scale axis for upwind, downwind and homogeneous conditions at the 1/3 octave bands of central frequencies (a) 100 Hz and (b) 1000 Hz.

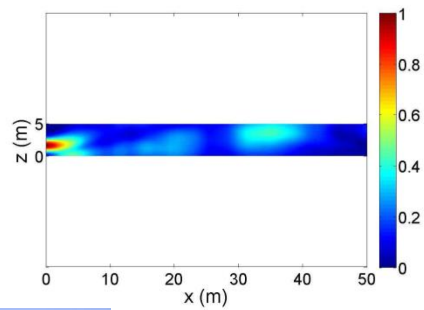
G. GUILLAUME *et al.* INTER-NOISE – 4-7 SEPTEMBER 2011

EM2PAU_2012

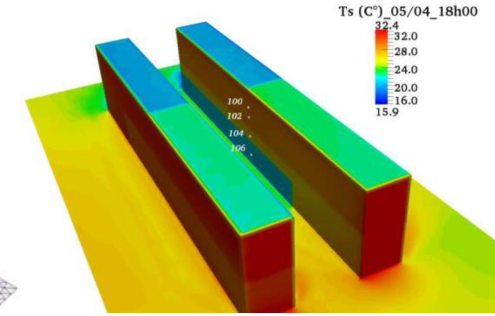
EXP : soufflerie ECN

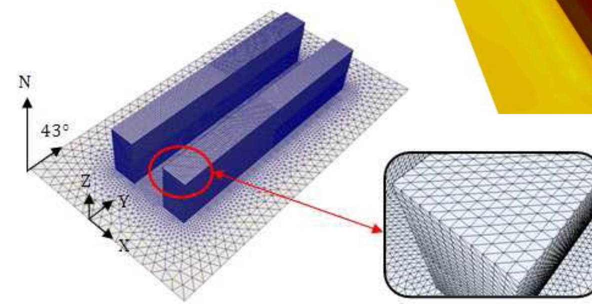
NUM : acoustique (PE)

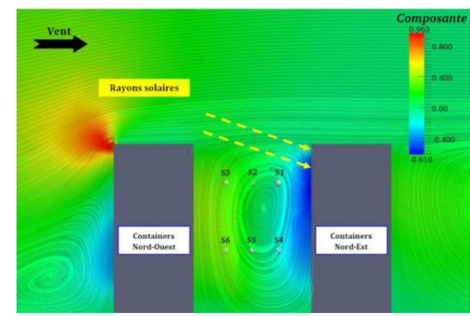




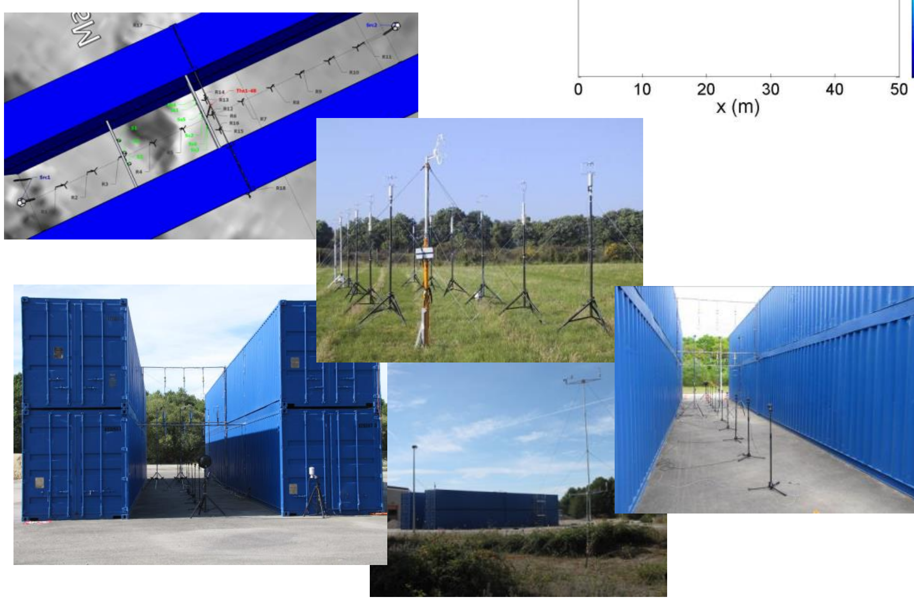
NUM : météo (Saturne)

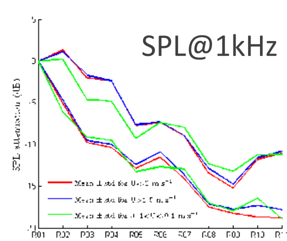


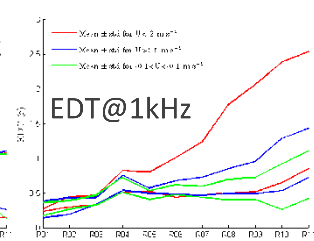




EXP : maquette Ifsttar

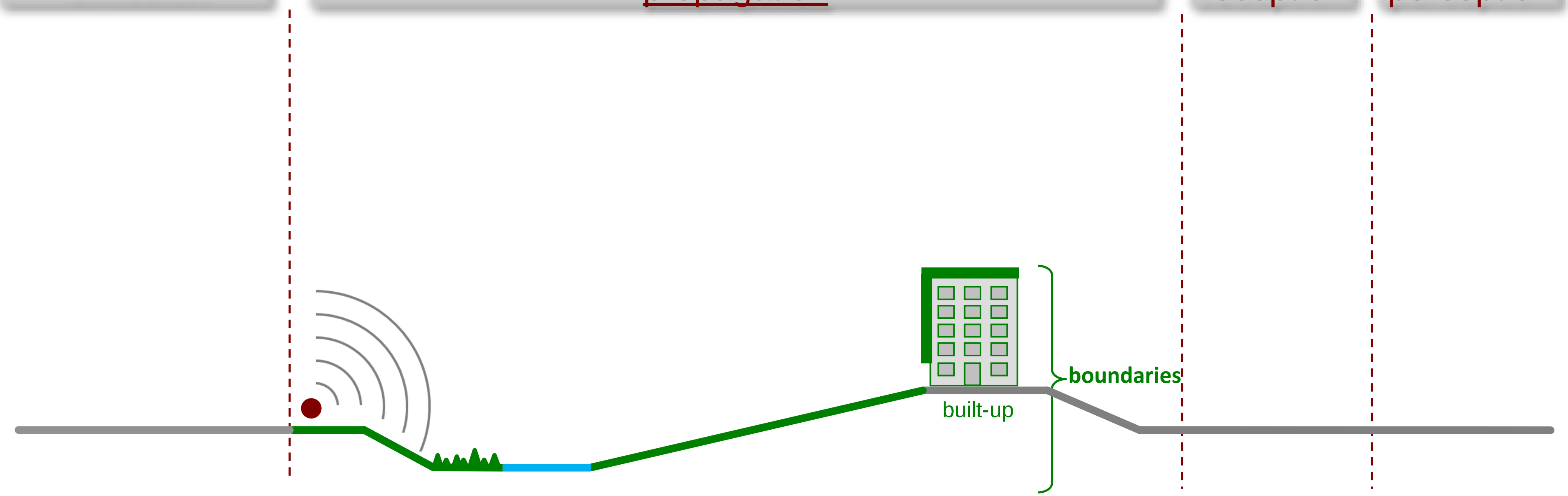






Veg-DUD_2014

emission | propagation | reception | perception



Veg-DUD_2014

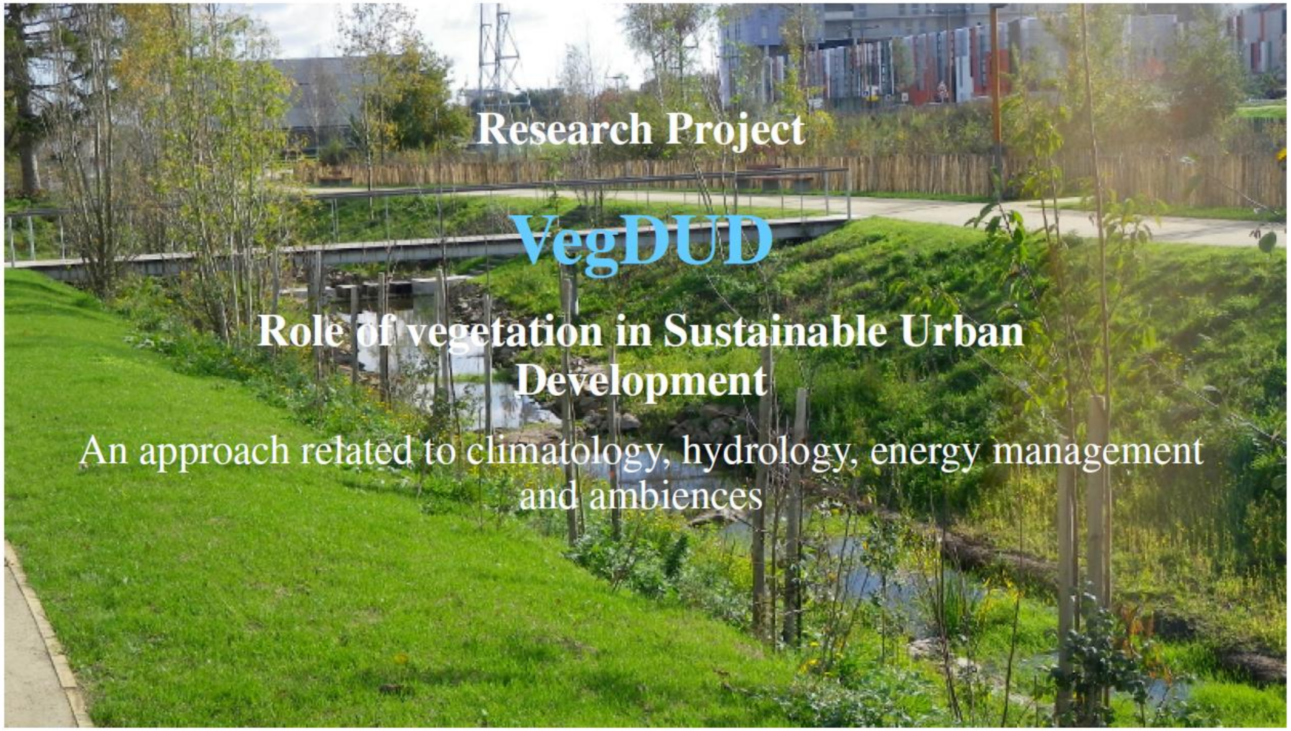
ANR Villes durables 2009

















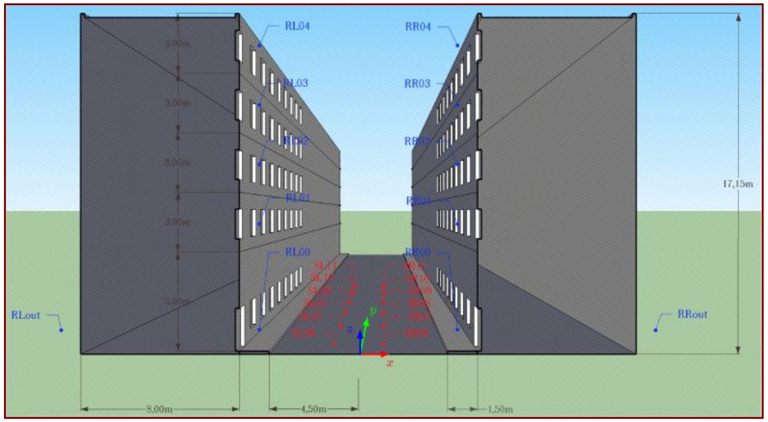
Veg-DUD_2014

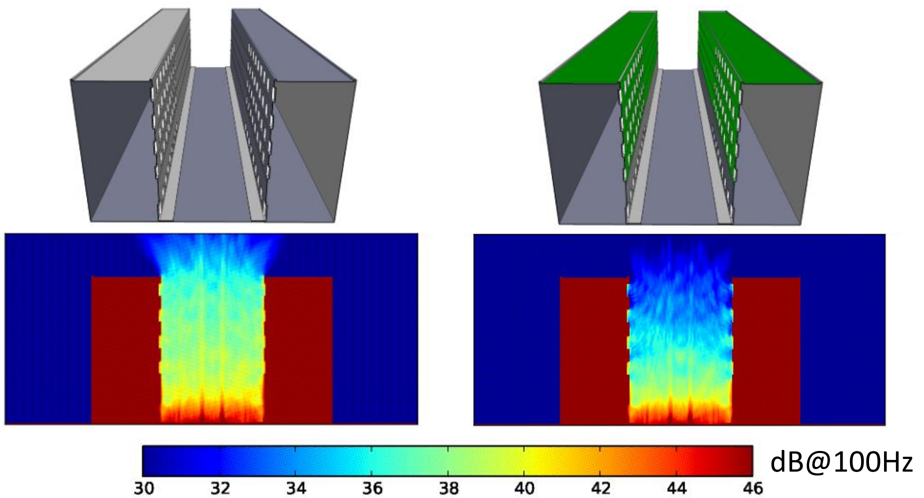
Experimental

- *in-situ* measurements of acoustic absorption properties (impedance) of vegetalized surfaces (roofs and facades)

Numerical

- Qualitative and quantitative parametric studies at several points using different indicators



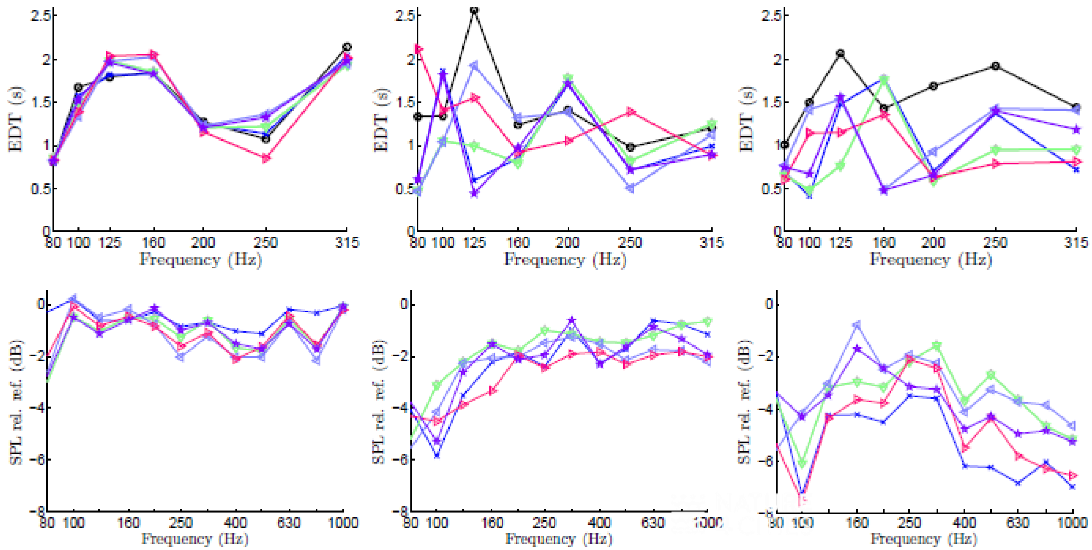


[Guillaume et al. JSTE 2014] [Guillaume et al. QAE Ed. 2014] [Guillaume et al. App. Acoust. 2015]

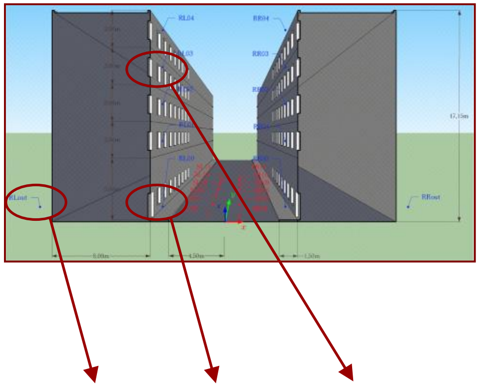
Veg-DUD_2014

EDT *(3D)*

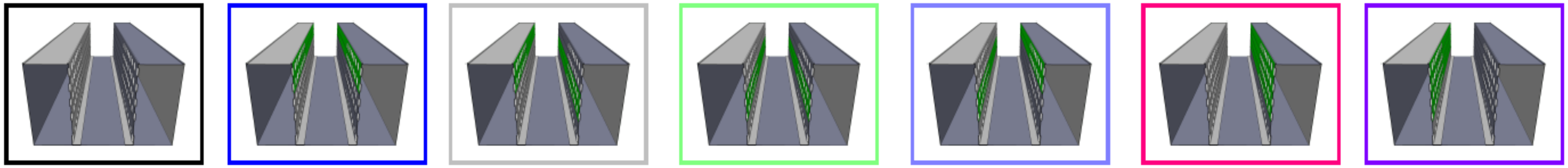
SPL *(2D)*



RL00 RL03 RLout

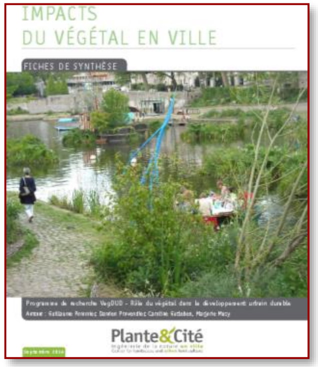


RLout RL00 RL03



FL14_0-FR14_0 (reference) | FL12_0-F34_100-FR12_0-FR34_100 | FL12_0-FL34_100-FR12_100-FR34_0 | FL12_100-FL34_0-FR12_100-FR34_0 | FL12_100-FL34_0-FR12_0-FR34_100 | FL14_0-FR14_100 | FL14_100-FR14_0

http://www.plante-et-cite.fr

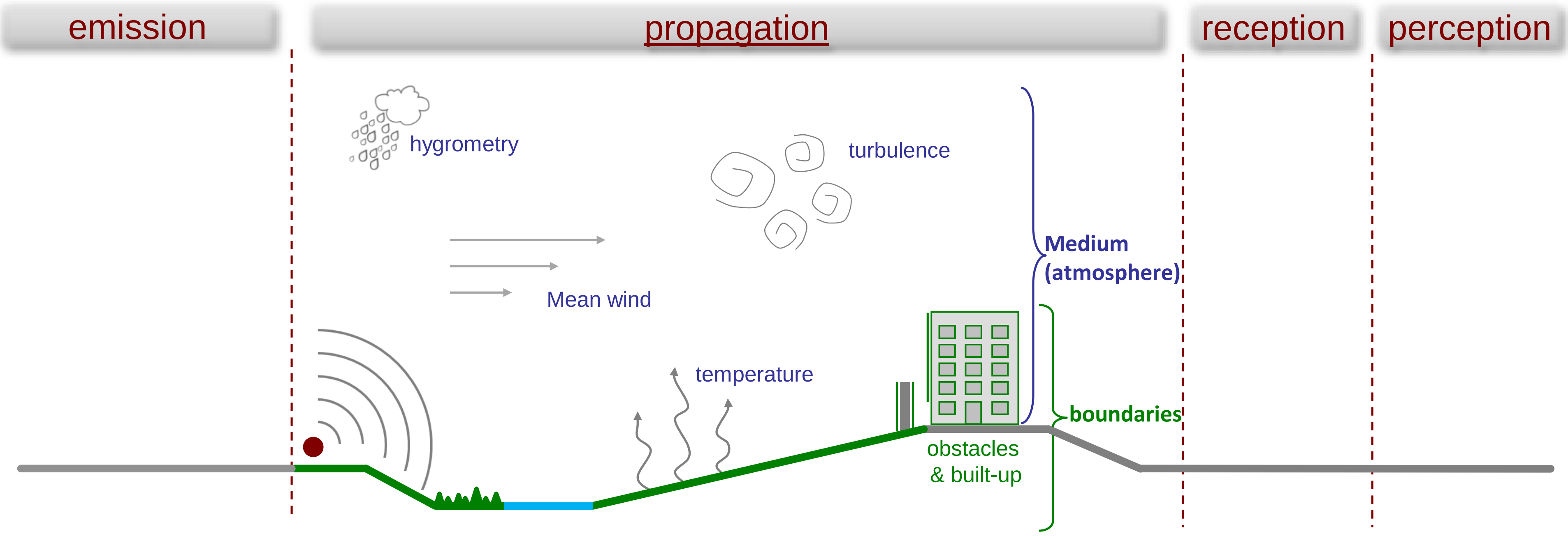


NATURE 4 CITIES

2017-2020 (EU, H2020)

http://www. nature4cities.eu

EUREQUA_2016



Environmental quality at district scale: A transdisciplinary approach within the EUREQUA project

B. Gauvreau, G. Guillaume, A. Can
Laboratoire d'Acoustique Environnementale (LAE)
www.umrae.fr

N. Gaudio, J. Lebras, A. Lemonsu, V. Masson
Laboratoire d'Acoustique Environnementale (LAE)
http://www.cnrm-game-meteo.fr

B. Carissimo
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http://cerea.enpc.fr

I. Richard
Environnons Consulting
http://www.tfconsultant.fr/nous-sommes/isabelle-richard

S. Haouès-Jouve
Laboratoire Interdisciplinaire Solidarités Sociétés Territoires (LISST)
www.lisst.univ-tlse2.fr

QUALITÉ ENVIRONNEMENTALE DES QUARTIERS

Financial support of the ANR 2012-2017

Multidisciplinary Assessment and Environmental Requalification of neighbourhoods

Objectives: Objectify and assess the environmental quality at neighbourhood scale through the identification of relevant criteria related to:

- The characterization of the physical environment *(climate, acoustics, air quality)* through *in situ* measurements and numerical simulations >> ***Objective / Quantitative approach***
- The evaluation of the quality of life by residents and users (inquiries) >> ***Subjective / Qualitative approach***

3 key dimensions:

- Interdisciplinary purpose
- Participatory dimension
- Operational ambition

Building a multidisciplinary consortium

Networks issued from previous projects, e.g. VegDUD, PIRVE, etc.

3 dimensions

Environmental quality

Microclimatic ambiance | Air quality | Sound environment

3 approaches

In situ measurements | Numerical simulation | Social and sensitive surveys (inquiries)

2 communities

Engineering Sciences (SPI)

meteorologists, numerical physicists, geomaticians, acousticians, etc.

Social and Human Sciences (SHS)

geographers, sociologists, psychologists, urban planners, architects, etc.

Météo-France (CNRM-GAME)
IFSTTAR/LAE
CEREA (UMR EDF/ENPC)

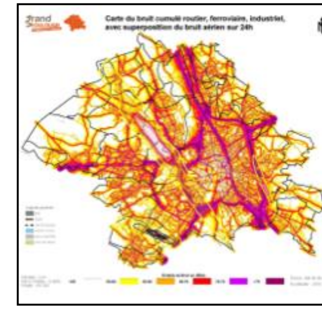
Professionals :
IAU-IdF
Ateliers Lion

Local stakeholders :
Toulouse Métropole
Ville de Marseille

LISST *(Univ. Toulouse)*
LATTS *(Univ. Paris Est)*
LPED *(Univ. Marseille)*
LRA *(Archi. Toulouse)*

How selecting the studied areas ?

Departure point: Nuisances
- Mobilisations in the media
- Views of experts
- Field visits
- Criteria:



- 3 areas affected by strong nuisances (noise and air pollution)
- Neighborhoods socialy differenciated and various urban morphologies
- Areas likely to be requalified in the mid-term

Paris : Porte de Bagnolet

Toulouse : Bordelongue-Papus-Tabar

Marseille : La Valbarelle

First SHS diagnosis of the neighborhoods

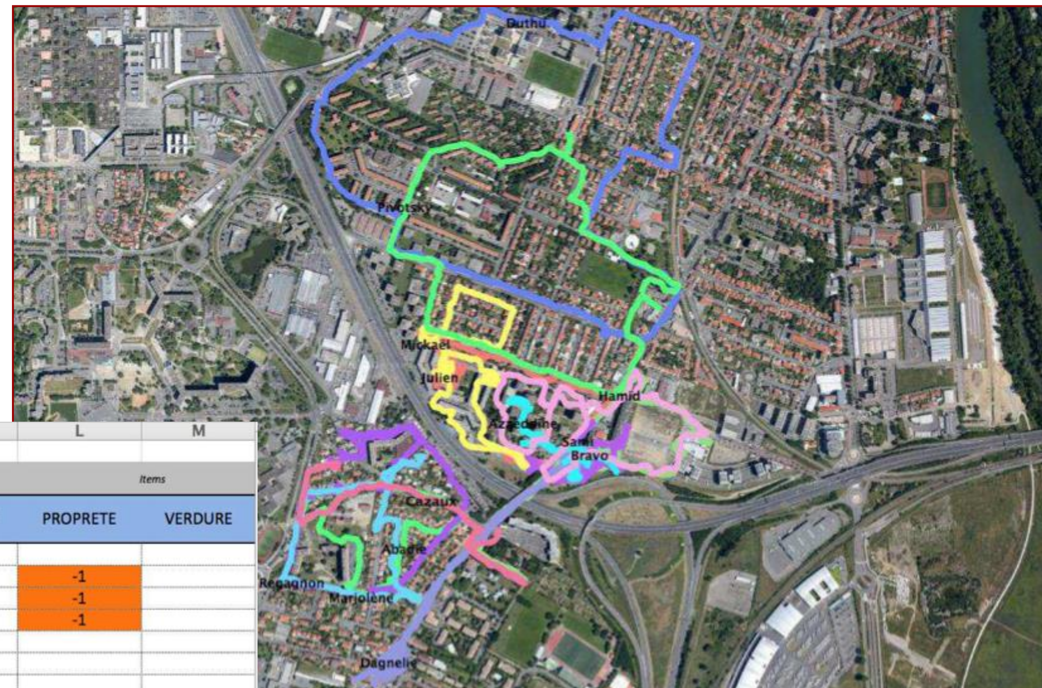
EUREQUA
QUALITÉ ENVIRONNEMENTALE DES QUARTIERS

Objectives: How do people perceive the environmental quality of the neighbourhood they live in?

Methodology: An exploratory survey (20 inhabitants per zone)

- Free commented walks: A kind of multisensory appraisal tool
- Interviews

GPS traces of the «free commented routes»



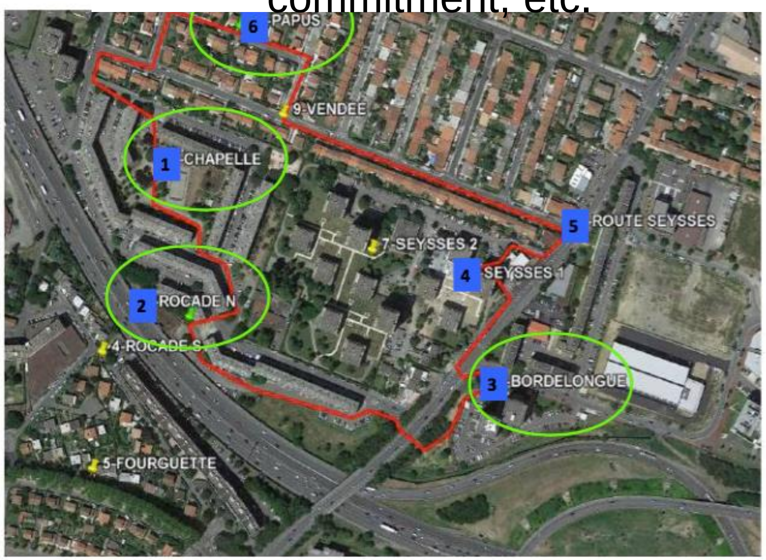
	E	F	G	H	I	J	K	L	M
1									
2	Nom de l'objet désigné	Coordonnées WGS84 de l'objet						Items	
3–4	OBJET	X_LON	Y_LAT	Z_EL	BRUIT	POLLUTION	CLIMAT	PROPRETE	VERDURE
5	City stade				1				
6	Jeux d'enfants / petit parc de Tabar							-1	
7	Hall d'immeuble							-1	
8	Parking de la rocade contre mur anti-bruit				-1	-1		-1	
9	Porche peint								
10	Petit jardin contre rocade				-1				
11	Rocade				-1				
12	Passage piéton sous la rocade								
13	Papus (pavillons castor)				1				1
14	Piscine Papus						1		
15	Petit jardin contre rocade						1		1
16	Immeubles de Tabar contre la rocade				-1	-1			

Thematic analysis

Some results of the diagnosis

- An acute expertise of the living environment and an extensive definition of environmental quality
  - Noise, air quality and climate comfort
  - But also: nature, cleanliness, aesthetics, sense of security, etc.

- A strong overlap between environmental and social issues
  - Environmental concernment is socially determined: Values and systems of constraints interfere in the way people prioritize environmental and social amenities
  - Various attitudes to environmental nuisances: Concealment, acceptance, commitment, etc.



Identification of iconic places

➔ Enrollment in a residential trajectory, aptitude to self organizing, ability to interpellate urban stakeholders, etc.

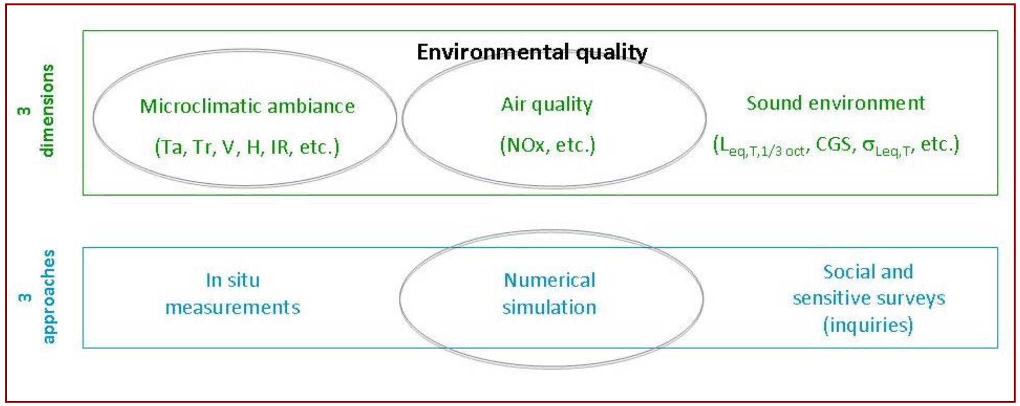
➔ Environmental psychology, sociological geography (transdisciplinarity)

➔ Importance of the inhabitants speech…

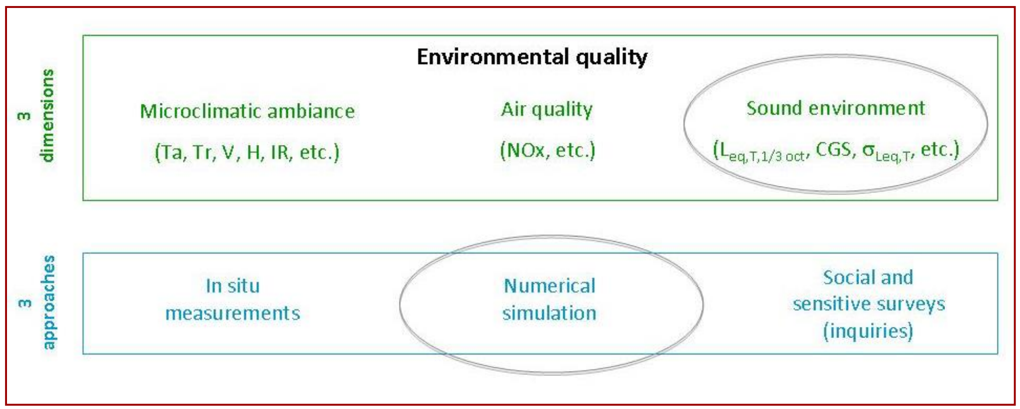
➔ … scientists are not the only "experts" !

Outline

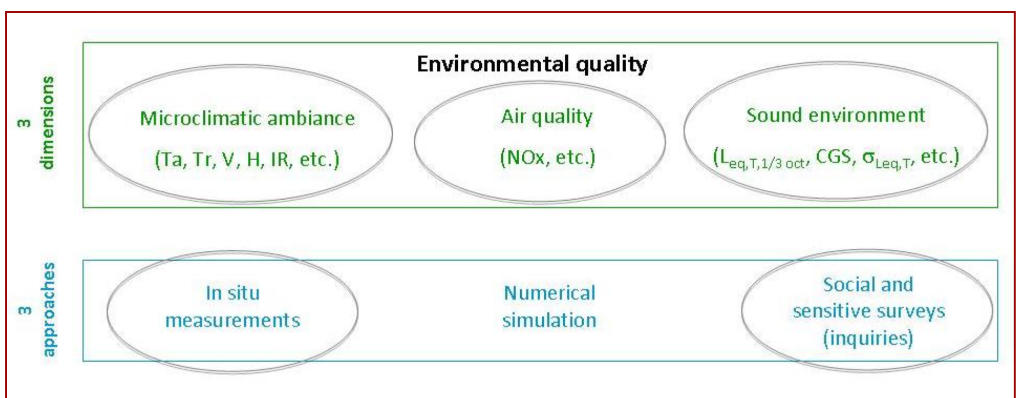
Focus 1:



Focus 2:



Focus 3:



Engineering Sciences (« SPI »)

3 dimensions

Environmental quality

Microclimatic ambiance

(Ta, Tr, V, H, IR, etc.)

Air quality

(NOx, etc.)

Sound environment

($L_{eq,T,1/3\ oct}$, CGS, $\sigma_{Leq,T}$, etc.)

3 approaches

In situ measurements

Numerical simulation

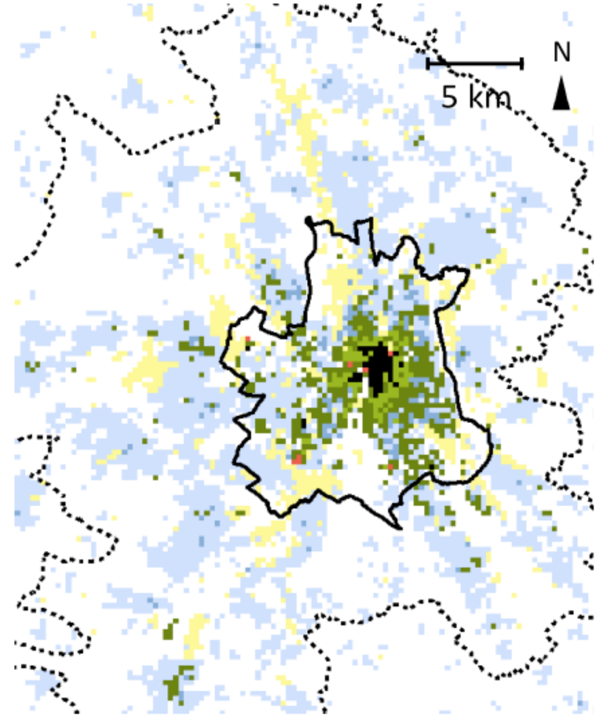
Social and sensitive surveys (inquiries)

Simulation of urban atmosphere

Meso-NH (CNRM)

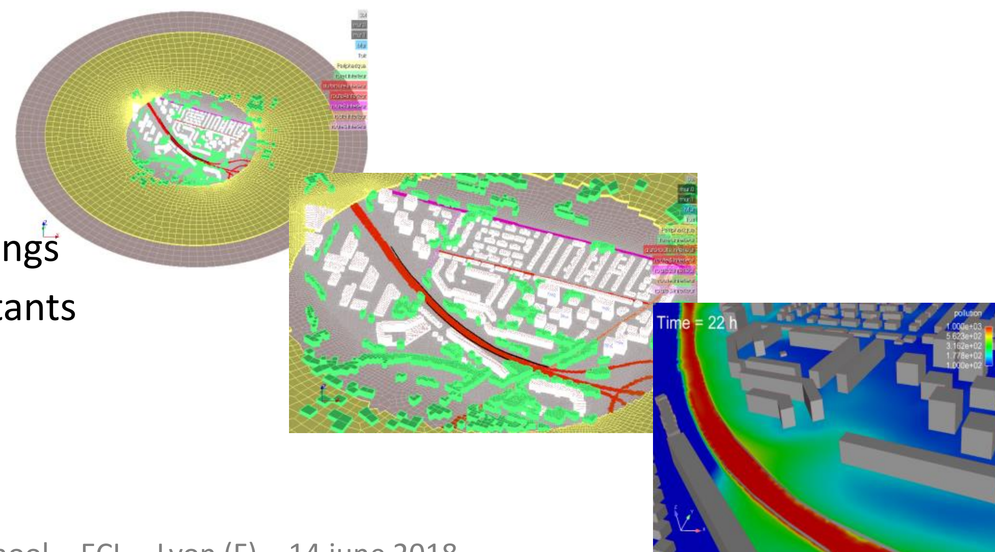
- Simulates wind, temperature, humidity, turbulence, clouds, etc...
- The surface is initialized using fine building data, but *aggregated at 100m of resolution*

Légende		
house		
houses		
Small buildings		
Dense buidlings		
High-rise		
historical		
industrial		



Code_Saturne (CEREA)

- Wind, temperature & turbulence profiles from MesoNH given each hour to Code_Saturne
- CFD modeling, with explicit buildings
- Numerical simulation of air pollutants dispersion

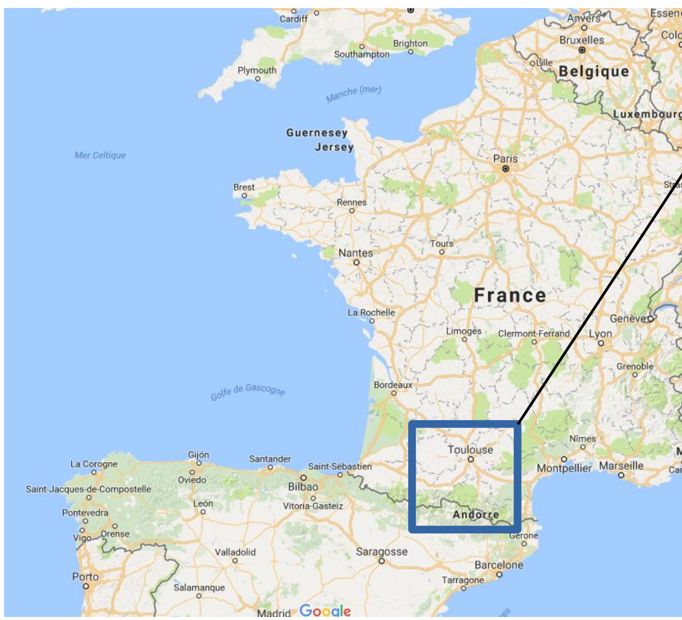


Simulation of urban atmosphere

Meso-NH (CNRM)

- 1 model at 500m of resolution
- 1 model at 100m of resolution

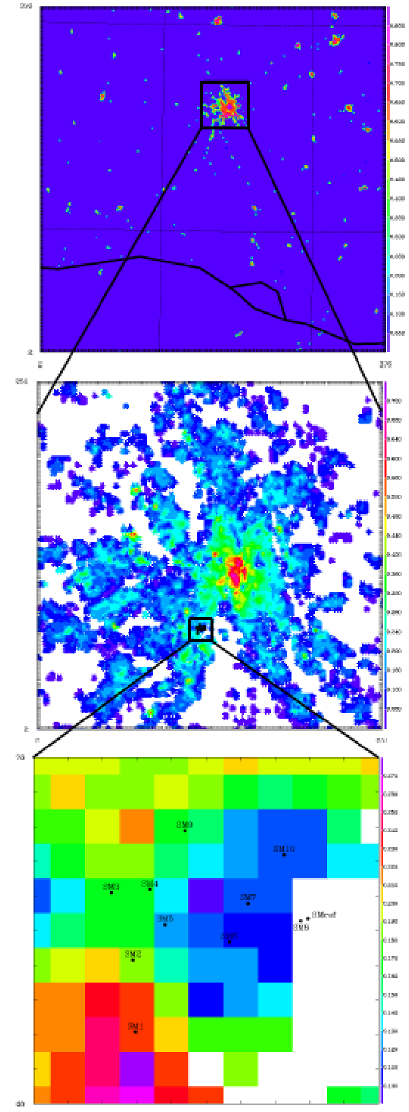
- Simulates wind, temperature, humidity,
- turbulence, clouds, etc...



Model 1 (urban)

Model 2 (building density)

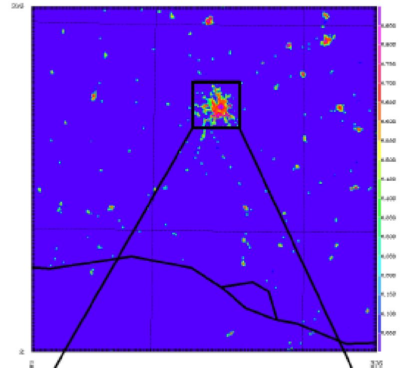
Zoom in Model 2



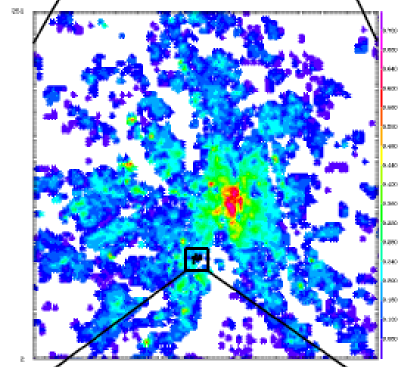
Simulation of urban atmosphere

- Meso-NH (CNRM)
  - 1 model at 500m of resolution
  - 1 model at 100m of resolution
  - Simulates wind, temperature, humidity,
  - turbulence, clouds, etc...

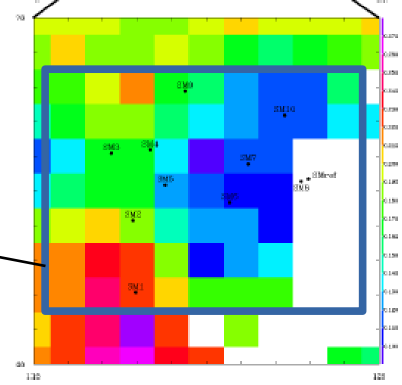
Model 1 (urban)



Model 2 (building density)



Zoom in Model 2

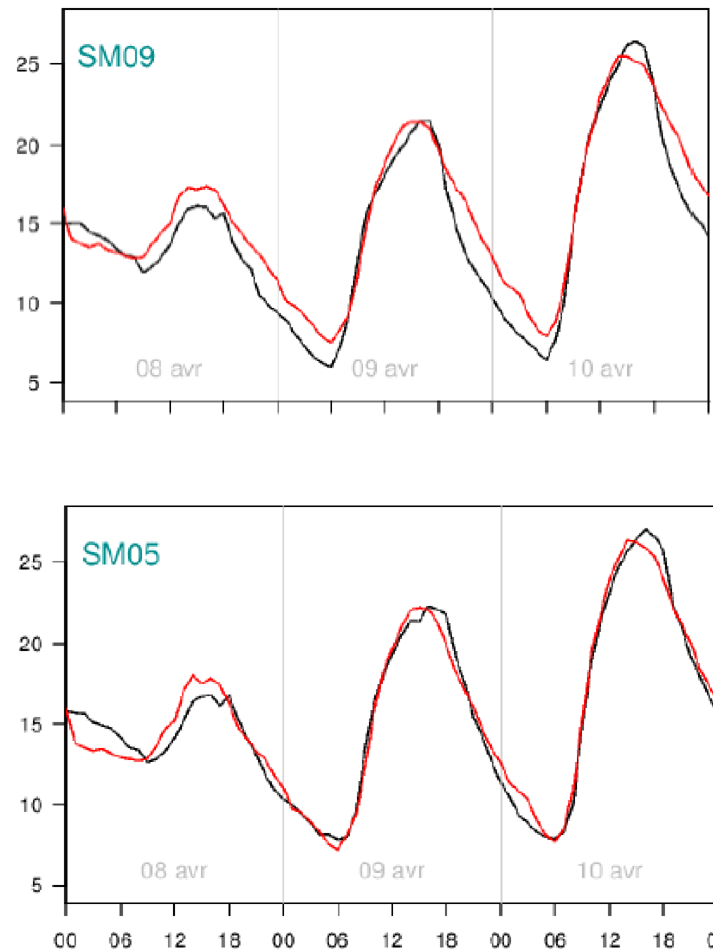


Simulation of urban atmosphere

Meso-NH (CNRM)

- **Model** validated with on-site **observations**

Air temperature

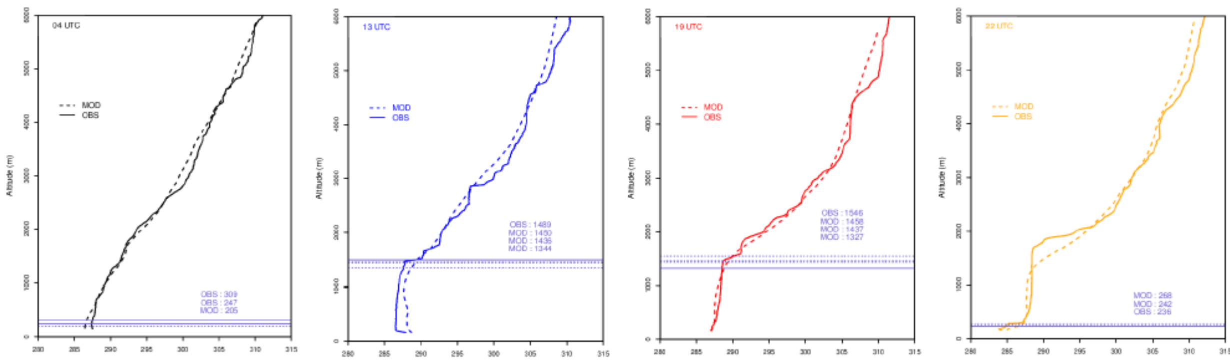


Simulation of urban atmosphere

Meso-NH (CNRM)

- **Model**
- validated
- with altitude
- **observations**

Air temperature vertical profiles



Engineering Sciences (« SPI »)

3 dimensions

Environmental quality

Microclimatic ambiance	Air quality	Sound environment
(Ta, Tr, V, H, IR, etc.)	(NOx, etc.)	($L_{eq,T,1/3\ oct}$, CGS, $\sigma_{Leq,T}$, etc.)

3 approaches

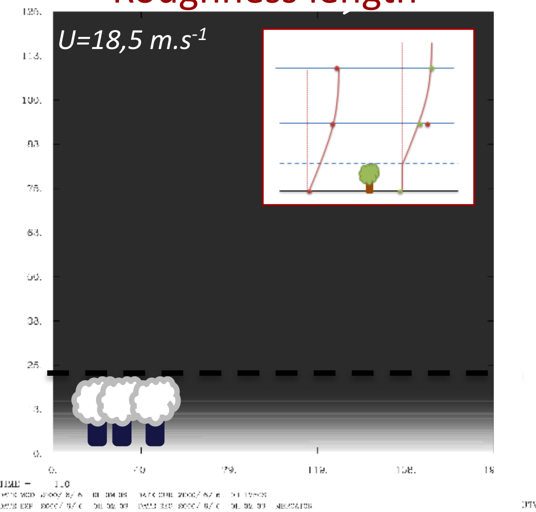
In situ measurements	Numerical simulation	Social and sensitive surveys (inquiries)

How chaining numerical models ?

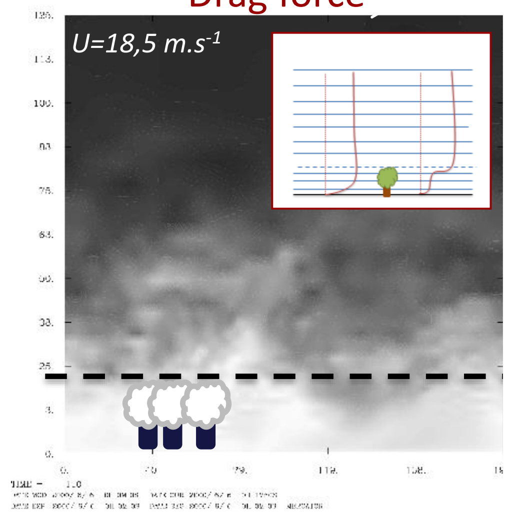
In open field

- Acoustics (PE, TLM, FDTD) // Micrométéo (CFD, Meso-NH, ARPS) >> cf. Bonus
- Exemple : PhD P. Aumond (Ifsttar / Météo-France, 2011) >> Meso-NH // TLM

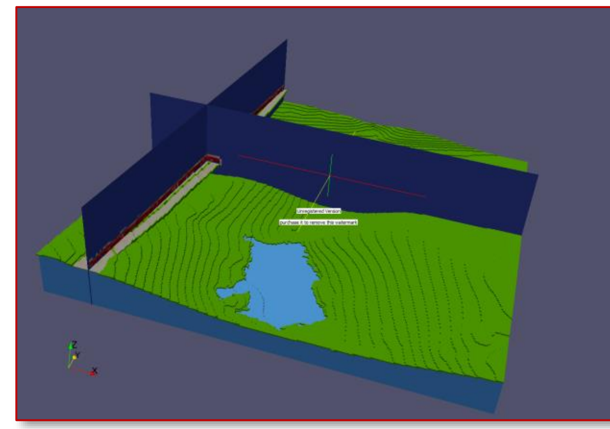
Roughness length



Drag force

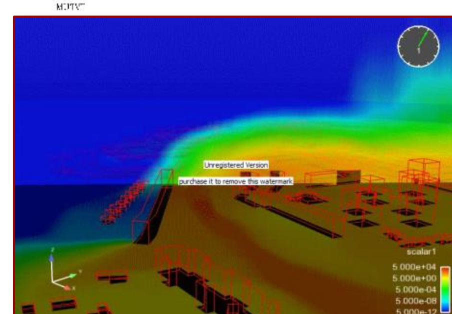


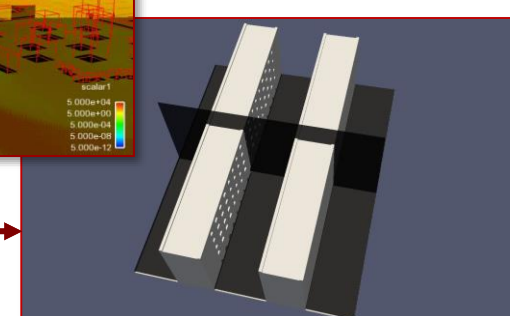
Sound propagation



In urban medium

- Example: CFD // TLM
- Challenge: wind + turbulence / TLM
- R&D: still under progress…

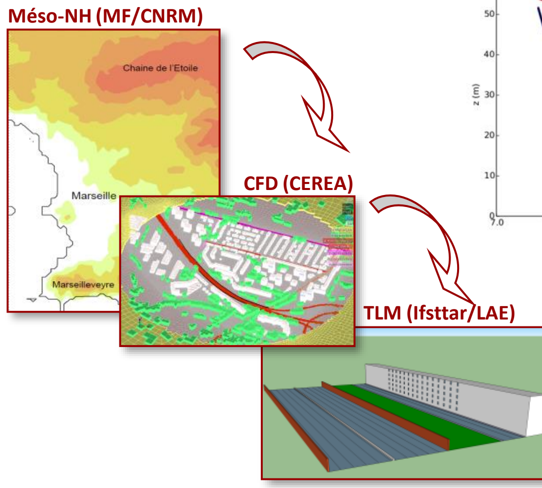


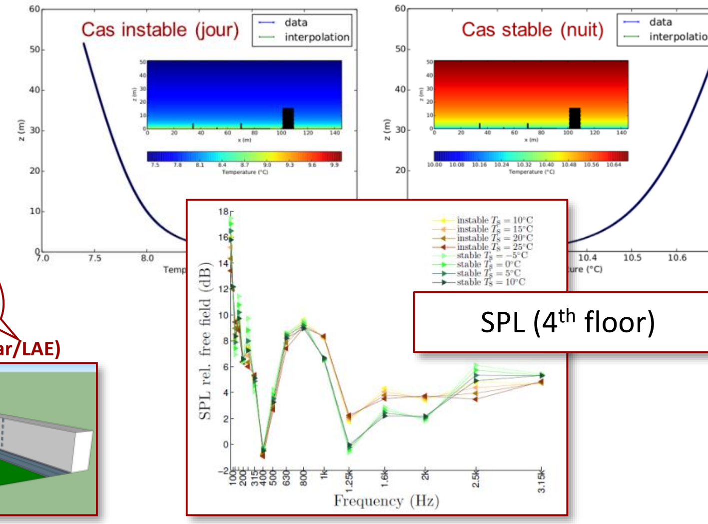


Reference vs simplified models

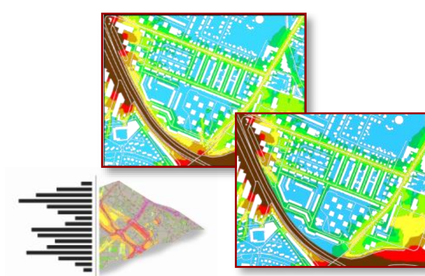
- **Reference models (research lab.)**
  - Almost all physical phenomena are taken into account
  - Focus: Toulouse neighborhood

Source: G. Guillaume (post-doc 2013-2014)





- **Simplified models (engineering topics, impact studies)**
  - Method: NMPB2008 >> NF S 31-133 >> CNOSSOS-EU (Part 2)
  - Open source and free software: NoiseM@p



http://noisemap.orbisgis.org

in-situ campaigns (SHS + SPI)

3 dimensions

Environmental quality

Microclimatic ambiance

(Ta, Tr, V, H, IR, etc.)

Air quality

(NOx, etc.)

Sound environment

($L_{eq,T,1/3\ oct}$, CGS, $\sigma_{Leq,T}$, etc.)

3 approaches

In situ measurements

Numerical simulation

Social and sensitive surveys (inquiries)

EUREQUA
QUALITÉ ENVIRONNEMENTALE DES QUARTIERS

Joint campaigns of measurements & surveys

(Marseille: june 2013 ; Paris: october 2103 ; Toulouse: january, april and june 2014)

cf. example below

SPI + SHS (transdisciplinarity) ➔ "Instrumented and commented walks"

- Fix sensors (meteo)
- Fix sensors (air quality)
- Mobile measurements
- Inquiries walks
- Fix sensors (acoustics)
- Road traffic countdown

Joint campaigns of measurements & surveys

(Marseille: june 2013 ; Paris: october 2103 ; Toulouse: january, april and june 2014)

Experimental protocol

- *in situ* measurements: Fix sensors (24/24h, SR 10 sec) + mobile sensors (human + vehicle + balloon + GPS trace, 10s)
- Pedestrian walks lasting about 1h, every 3 hours (*i.e.* 3h, 6h, 9h, 12h, 15h, 18h, 21h, 24h) during 3 days + 1 night
- Additionnal walks: Synchronous surveys conducted together with inhabitants and users of the district
- Questionnaires filled at each "stop spots" + focus groups at the end
- Numerous physical indicators relative to Environmental Quality (EQ):
  - ✓ Climatic comfort: Air temperature, IR radiation, wind speed, relative hygrometry, perceived temp., UTCI, etc.
  - ✓ Air quality: NOx, CO_2, etc.
  - ✓ Sound environment: Raw data ($L_{eq\,\frac{1}{3}\,1s}$) + post-processed ($L_{10\,\frac{1}{3}}$, $L_{90\,\frac{1}{3}}$, L_{A50}, etc.) + analysis (σ_{LAeq}, $SGC_{50Hz\text{-}10kHz}$)

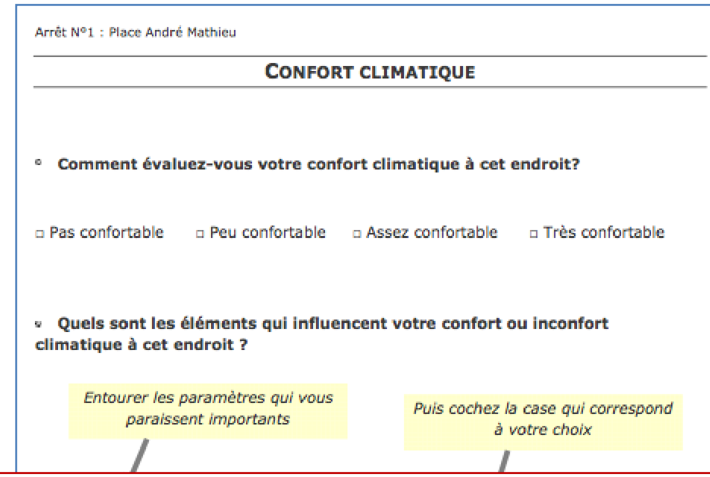
[Can et Gauvreau JASA 2015] [Can et al. Acta Acustica 2015] + COMs

Mobilizing inhabitants

Data post-processing and analysis

A very large database (SPI + SHS)

- Database: 1110 lines (∀ POI, ∀ season, ∀ hour, ∀ point, ∀ person) * 270 raws (∀ SPI and SHS index or parameters)
- 280 surveyed people
- Data quality: Post-processing and validation


Arrêt N°1 : Place André Mathieu

CONFORT CLIMATIQUE

- **Comment évaluez-vous votre confort climatique à cet endroit?**

□ Pas confortable □ Peu confortable □ Assez confortable □ Très confortable

- **Quels sont les éléments qui influencent votre confort ou inconfort climatique à cet endroit ?**

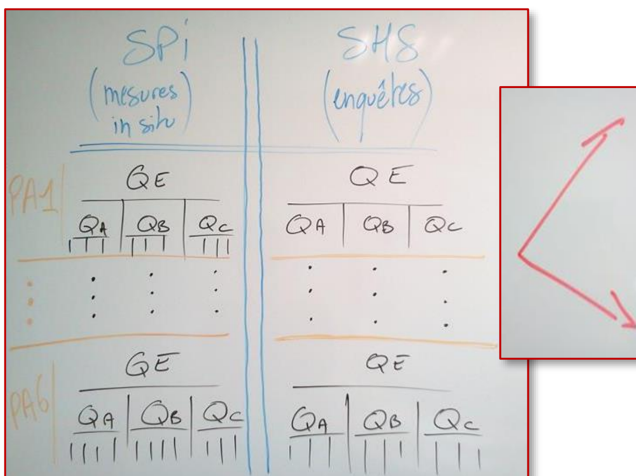
Entourer les paramètres qui vous paraissent importants

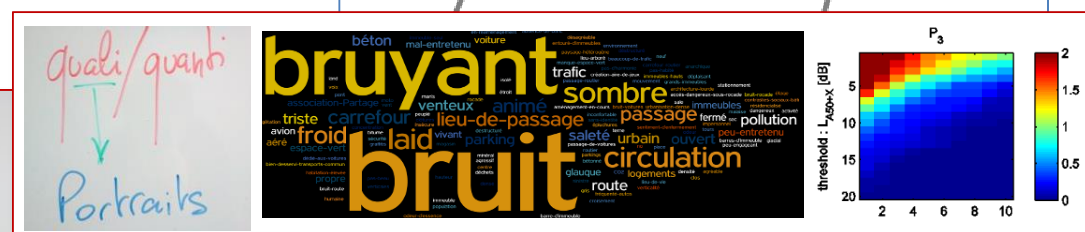
Puis cochez la case qui correspond à votre choix

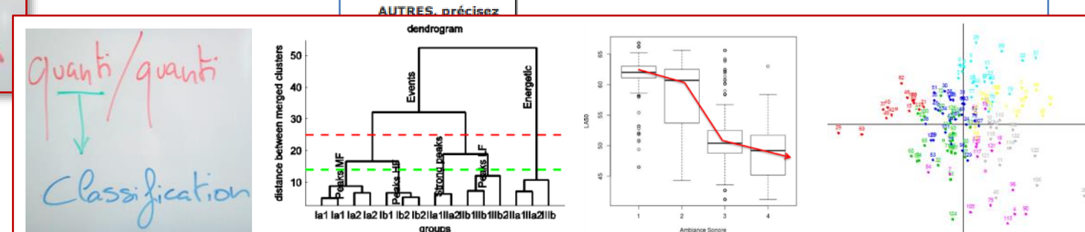
AUTRES, précisez

Statistical analysis

- Post-doc A. Amossé (LISST, 2016-217)
- SHS/SHS + SPI/SPI + SPI/SHS
- Cross analysis and hierarchical clustering
- Sensitive portraits (inquiries) // physical portraits (meas.)







in-situ campaigns (sound environment)

3 dimensions

Environmental quality

Microclimatic ambiance	Air quality	Sound environment
(Ta, Tr, V, H, IR, etc.)	(NOx, etc.)	($L_{eq,T,1/3\ oct}$, CGS, $\sigma_{Leq,T}$, etc.)

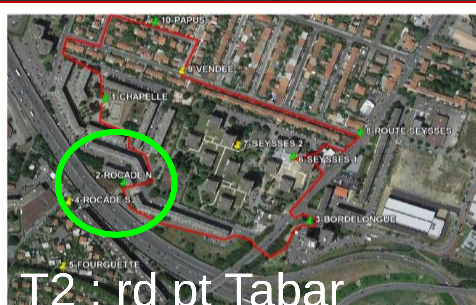
3 approaches

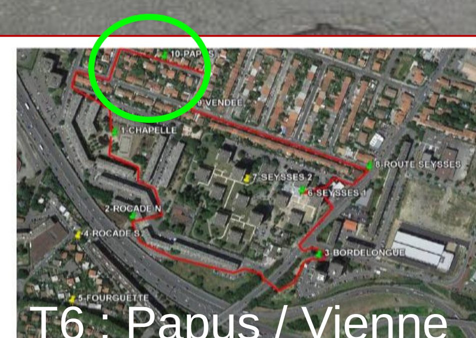
In situ measurements	Numerical simulation	Social and sensitive surveys (inquiries)

Sensitive & physical portraits of studied areas
2 extremes examples: T2 & T6

T2

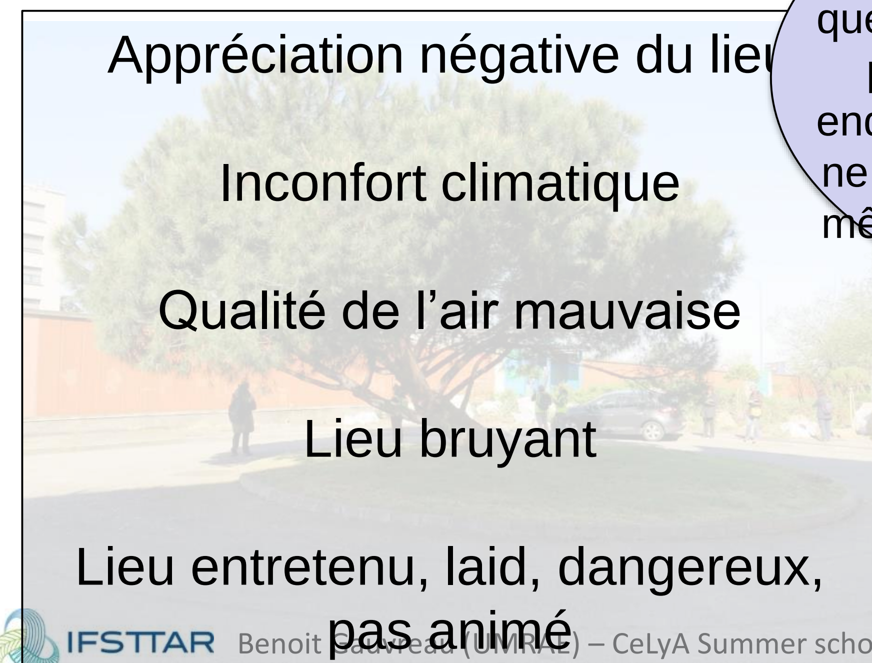
T6





Portrait sensible du point d'arrêt 2 : Rond point de Tabar

"C'est l'endroit le plus improbable. Un rond-point avec une seule entrée et une seule sortie, on peut faire que demi-tour. Qui peut venir là ? Pourquoi ? Même si on peut deviner. On se demande vraiment pourquoi cet endroit existe. C'est oppressant. Je sais pas où je suis, je ne sais pas par où il faudrait aller. Manque de repère. En même temps c'est bizarre parce que c'est un endroit que je connais bien à quelques mètres juste derrière la rocade. »
extérieur



Appréciation négative du lieu

Inconfort climatique

Qualité de l'air mauvaise

Lieu bruyant

Lieu entretenu, laid, dangereux, pas animé

"Il n'a rien pour lui à part un arbre. Un seul point positif que j'ai trouvé : il n'y a pas de problème pour garer sa voiture. »
extérieur

Rond point de Tabar

Arrêt 2

Confort climatique

<u>Point jugé inconfortable</u>

- Habitants : 76 %
- Extérieurs : 53 %

- Vent : point jugé venteux

Qualité de l'air

<u>Majoritairement mauvaise (88 %</u>

Point avec le + d'opinions très négatives
Mais 2ème pour les opinio négatives (après T5)

Évaluation QA repose surtout sur le trafic

Confort sonore

<u>Lieu bruyant</u>

Bruyant à 99 %
Point très désagréable à 99 %
Score le plus fort de tous les points

Autres critères

- Lieu entretenu (58 %)
- Endroit laid (80 %)
- Lieu dangereux (45 %)
- Lieu pas animé (83 %)

Appréciation négative du lieu quasi unanime

Surtout par les extérieurs (99% - hab: 91%)
+ effet saison (amélioration du temps = perception moins négative)

Portrait sensible du point d'arrêt 6 : rue de la Vienne

Appréciation positive unanime du lieu

Confort climatique

Bonne qualité de l'air

Lieu calme

Lieu entretenu, beau, sécure, pas animé

« On entend légèrement le trafic de la rocade, au loin, mais ça gêne beaucoup moins. Et au niveau de la pollution de l'air, on a l'impression qu'on respire mieux. Ce n'est qu'une impression, on le sait, mais c'est plus aéré, plus calme. »
habitant

"On se croit presque à la campagne. Le seul problème c'est les avions. »
habitant

Rue de la Vienne

Arrêt 6

Confort climatique

Point jugé confortable (83%)

- Chaleur et humidité : effet saison
- Vent : point jugé calme
- Point ensoleillé même si effet saison

Qualité de l'air

Majoritairement bonne (84%)

Habitants + critiques (81% - ext: 86

Pas d'effet saison

Critères : prédominance paysage (surtout pour les habitants)

Puis (absence) trafic et (absence) odeurs

Confort sonore

Lieu calme (90%)

Surtout le soir

Pas d'effet saison

Ambiance sonore agréable

Convergence entre confort et ambiance

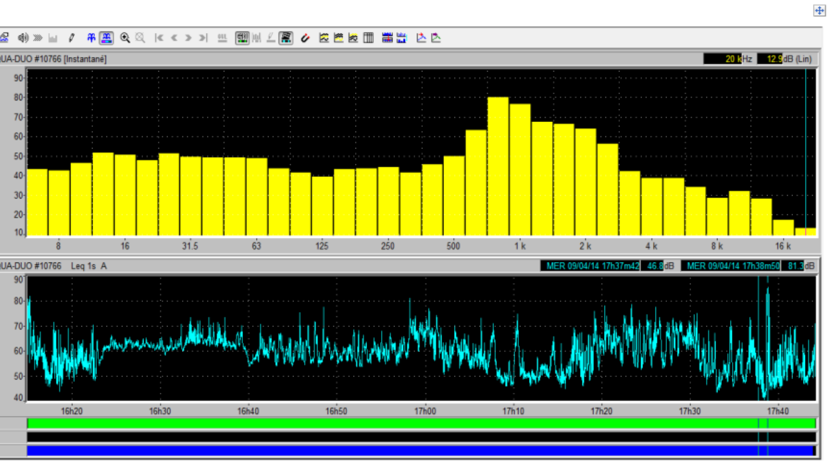
Autres critères

- Lieu entretenu (96%)
- Lieu plutôt beau (82%
- Lieu sûr (100%)
- Lieu pas animé (90%)

Lieu apprécié quasi unanimement

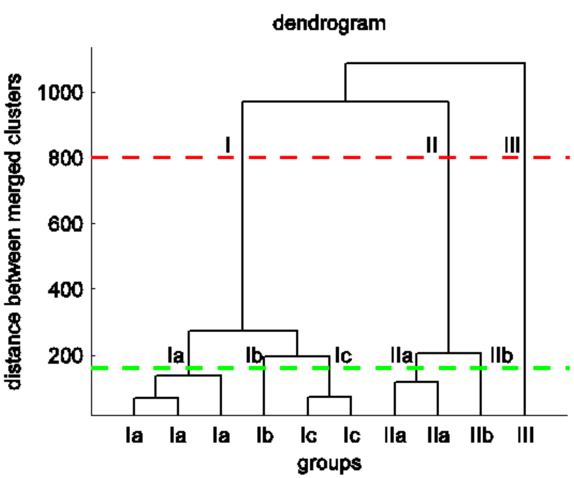
Davantage de fortes appréciations positives pour les habitants (95% - ext: 89%)

Data post-processing and analysis (ex. for acoustics)



	L_{Aeq}	L_{Amax}	L_{A10}	L_{A50}	L_{A90}	L_{Amin}	L_{A10}-L_{A90}	L_{Amax}-L_{Amin}	σ_{LAeq}	$\delta_{LAeq,1s}$	$\delta_{LAeq,2s}$	$SGC_{[20Hz\text{-}20kHz]}$
L_{Aeq}	1.00	0.94	0.98	0.94	0.87	0.85	0.57	0.48	0.55	0.27	0.50	-0.04
L_{Amax}		1.00	0.92	0.81	0.72	0.68	0.68	0.70	0.70	0.38	0.60	-0.01
L_{A10}			1.00	0.93	0.85	0.83	0.63	0.50	0.58	0.29	0.53	-0.03
L_{A50}				1.00	0.96	0.94	0.37	0.24	0.31	0.12	0.32	-0.09
L_{A90}					1.00	0.99	0.18	0.08	0.14	-0.01	0.18	-0.14
L_{Amin}						1.00	0.14	0.02	0.11	-0.04	0.15	-0.16
L_{A10}-L_{A90}							1.00	0.88	0.95	0.61	0.79	0.15
L_{Amax}-L_{Amin}								1.00	0.94	0.62	0.76	0.17
σ_{LAeq}									1.00	0.66	0.84	0.17
$\delta_{LAeq,1s}$										1.00	0.84	0.30
$\delta_{LAeq,2s}$											1.00	0.21
$SGC_{[20Hz\text{-}20kHz]}$												1.00

	L_{Aeq}	L_{20Hz}	$L_{31.5Hz}$	L_{63Hz}	L_{125Hz}	L_{250Hz}	L_{500Hz}	L_{1kHz}	L_{2kHz}	L_{4kHz}	L_{8kHz}	L_{20kHz}
L_{Aeq}	1.00											
L_{20Hz}	0.52	1.00										
$L_{31.5Hz}$	0.70	0.80	1.00									
L_{63Hz}	0.82	0.64	0.83	1.00								
L_{125Hz}	0.87	0.60	0.78	0.90	1.00							
L_{250Hz}	0.93	0.57	0.76	0.87	0.94	1.00						
L_{500Hz}	0.94	0.51	0.70	0.81	0.87	0.93	1.00					
L_{1kHz}	0.96	0.52	0.70	0.82	0.87	0.93	0.93	1.00				
L_{2kHz}	0.97	0.52	0.69	0.81	0.85	0.91	0.91	0.96	1.00			
L_{4kHz}	0.92	0.48	0.63	0.73	0.75	0.80	0.82	0.84	0.88	1.00		
L_{8kHz}	0.86	0.51	0.64	0.70	0.74	0.78	0.77	0.80	0.87	0.86	1.00	
L_{20kHz}	0.78	0.45	0.57	0.62	0.66	0.70	0.70	0.73	0.79	0.79	0.90	1.00



Hierarchical clustering

(Ward Method, k-means)

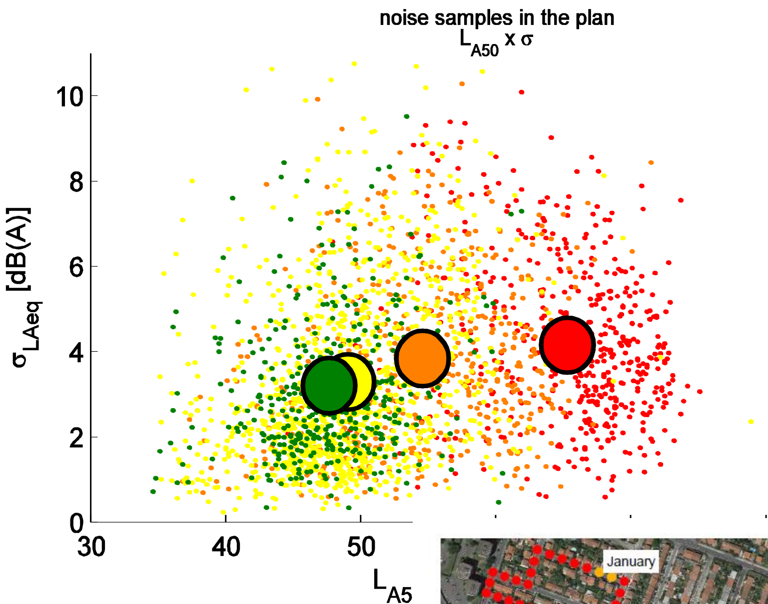
Chosen index:

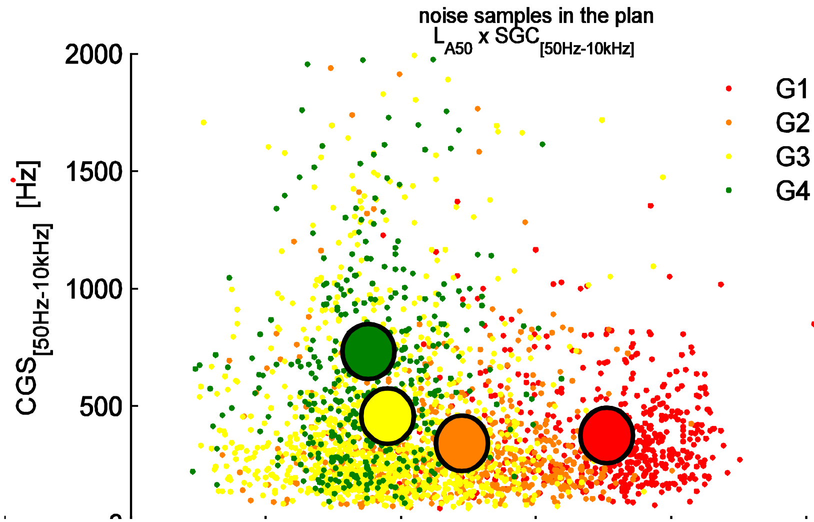
- LA50 : « dose »
- STD(Laeq) : « time profile »
- SGC[50Hz-10kHz]: « frequency profile »

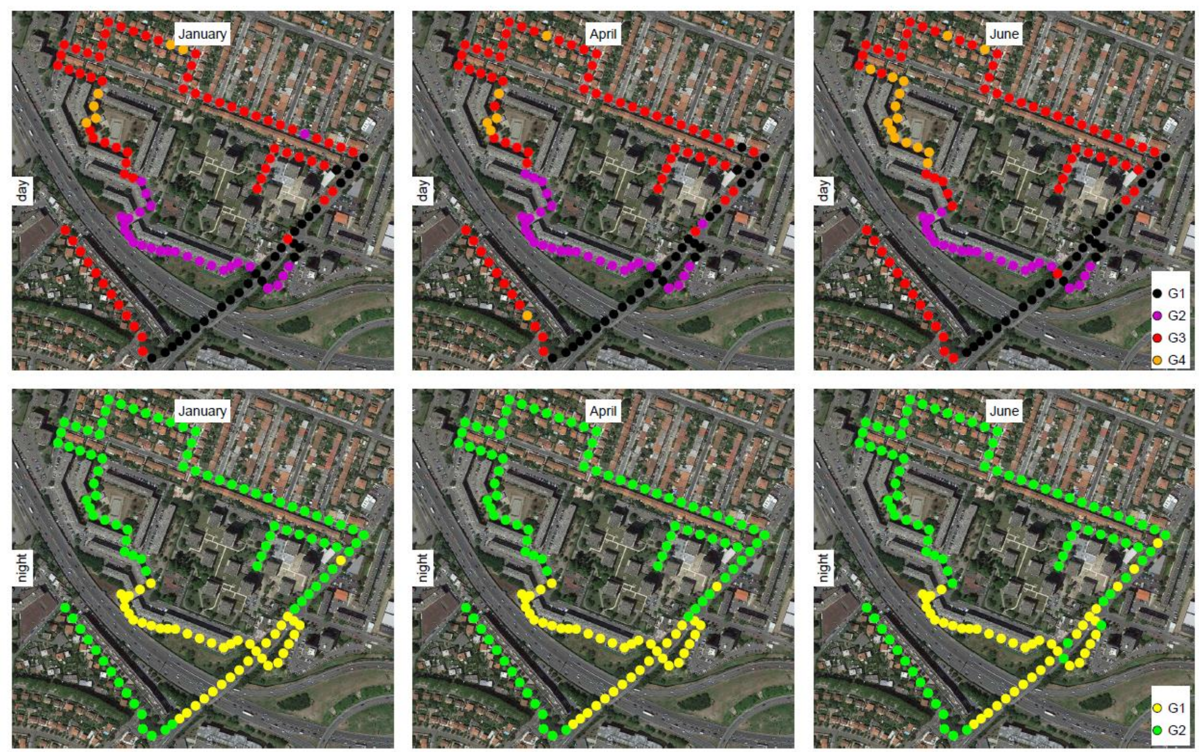
+ (only for SHS inquiries soundwalks):

- Percentiles LA90, LA10 & LA1 (dB)
- Mask Index MI_LA50 & MI LLF50 (%)

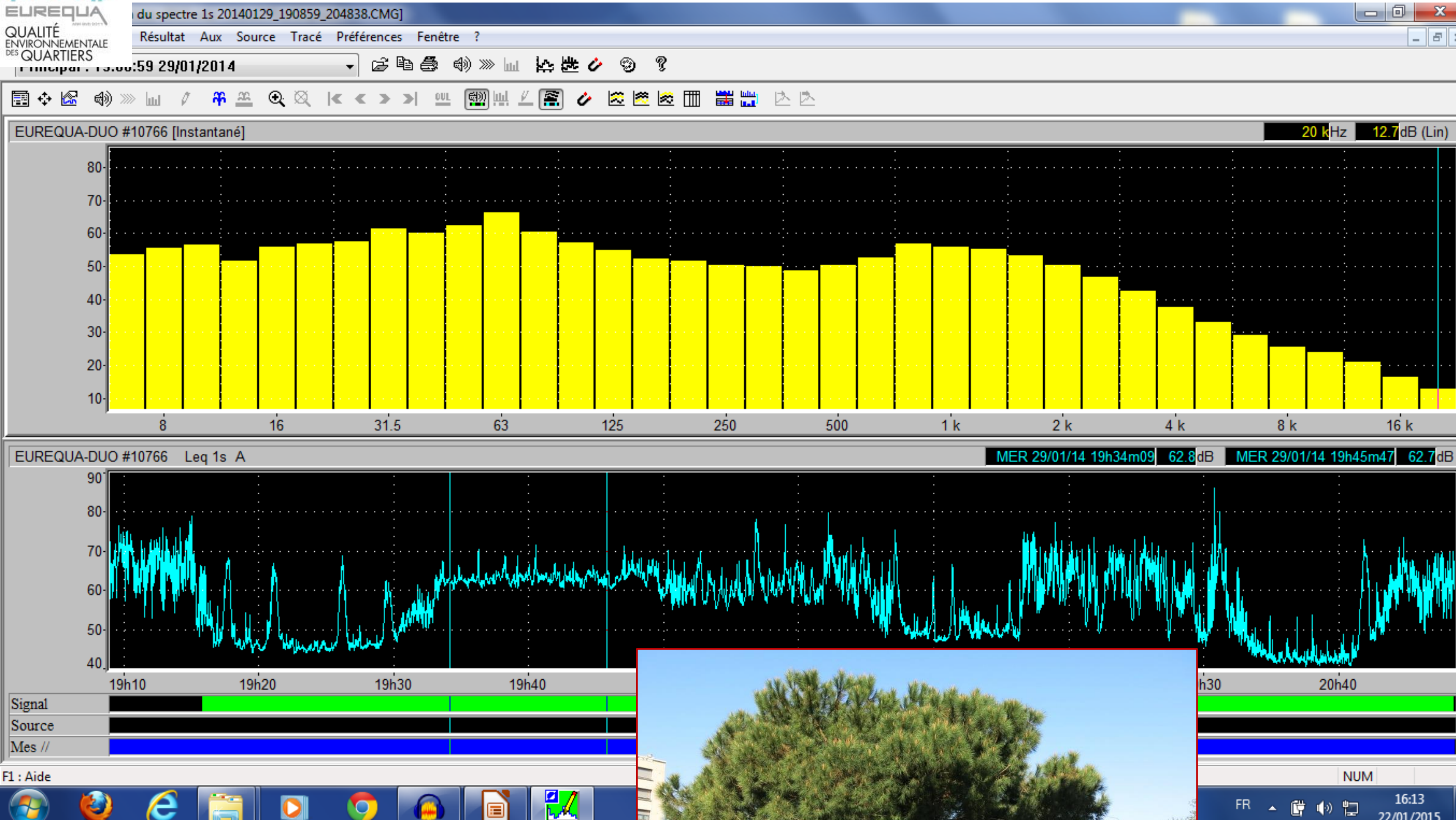
Data post-processing and analysis (ex. for acoustics)







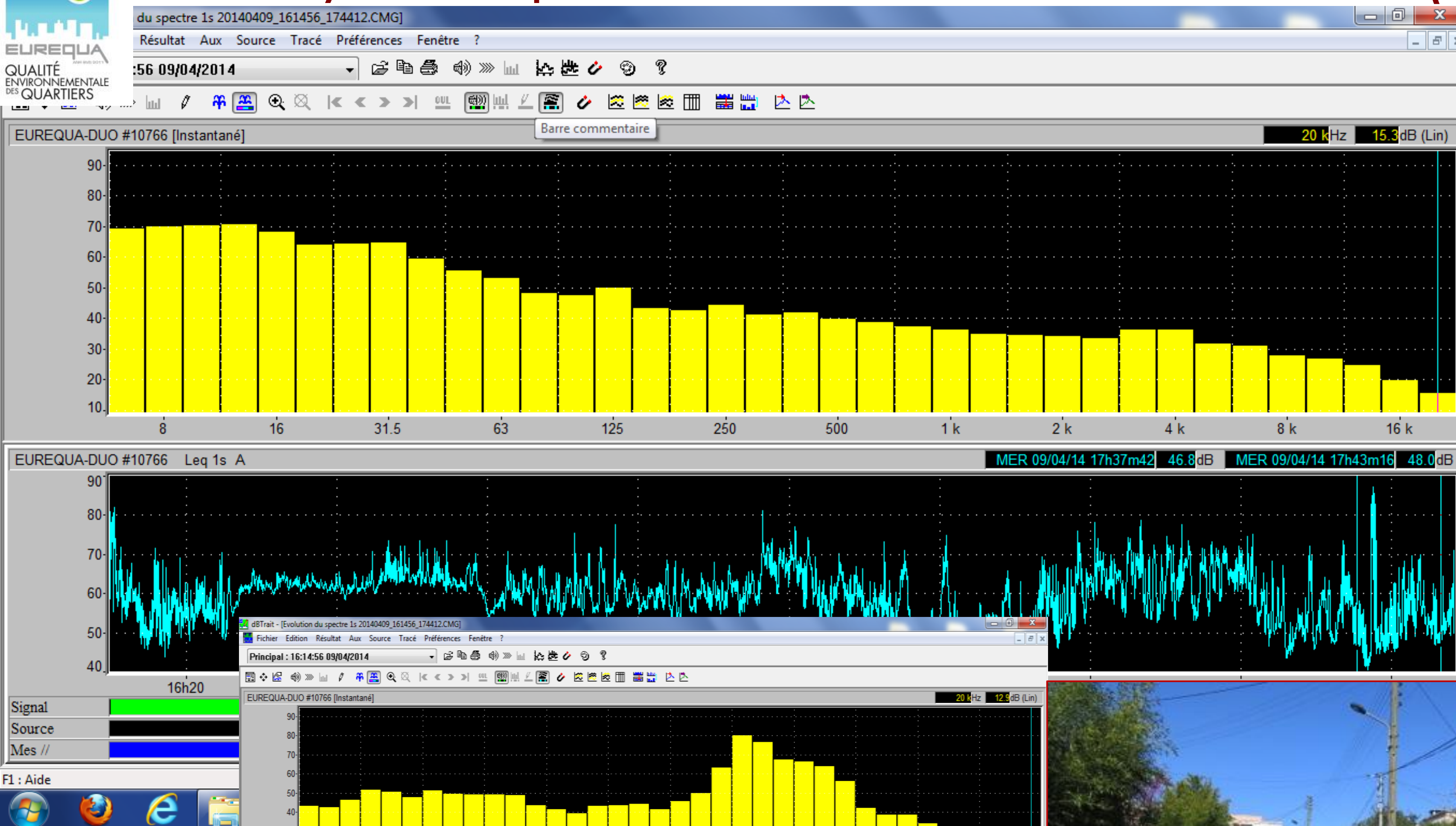
Physical portraits of studied areas (T2)

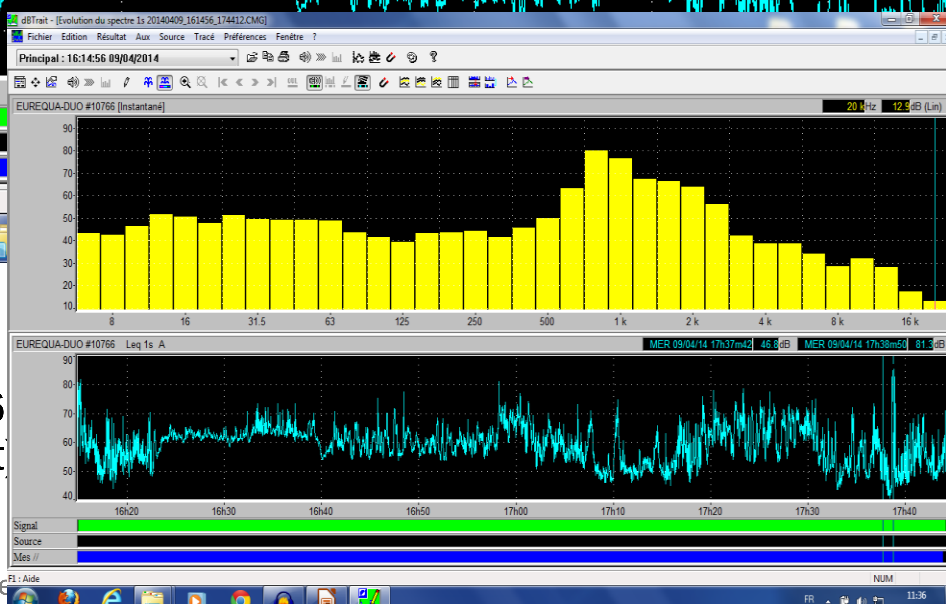


- LA50
- LA90
- LA10
- LA1
- STD
- CGS
- MI

T1_H19_P2

Physical portraits of studied areas (T6)



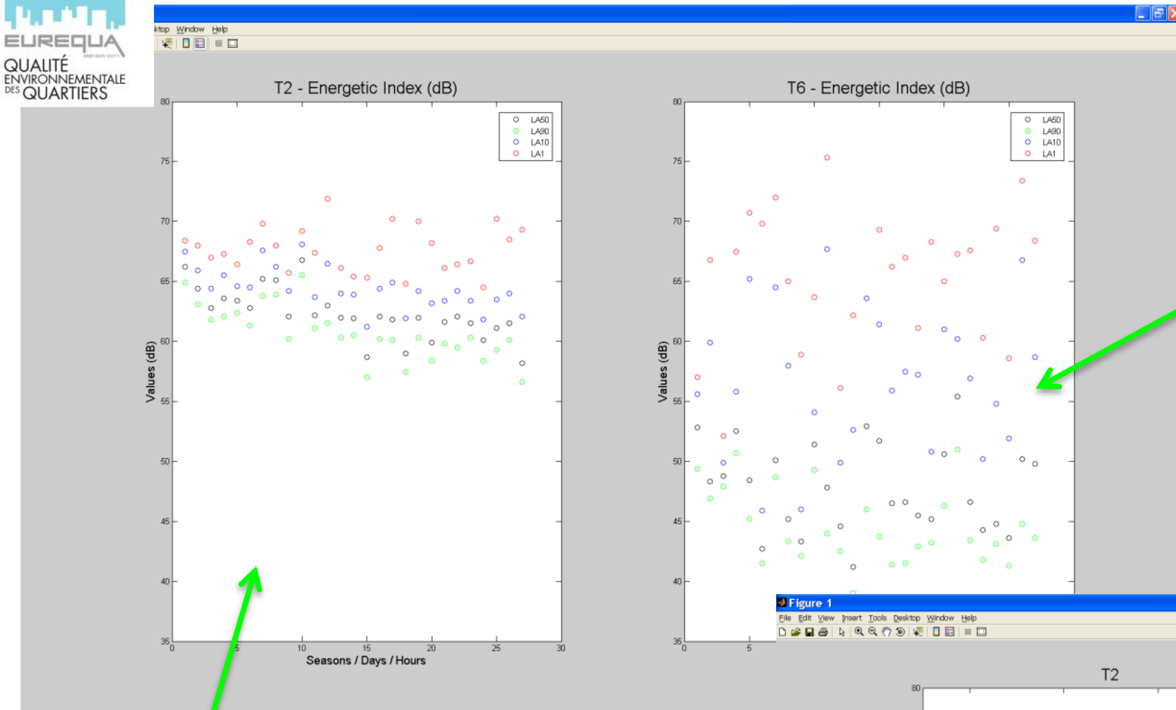


- LA50
- LA90
- LA10
- LA1
- STD
- CGS
- MI

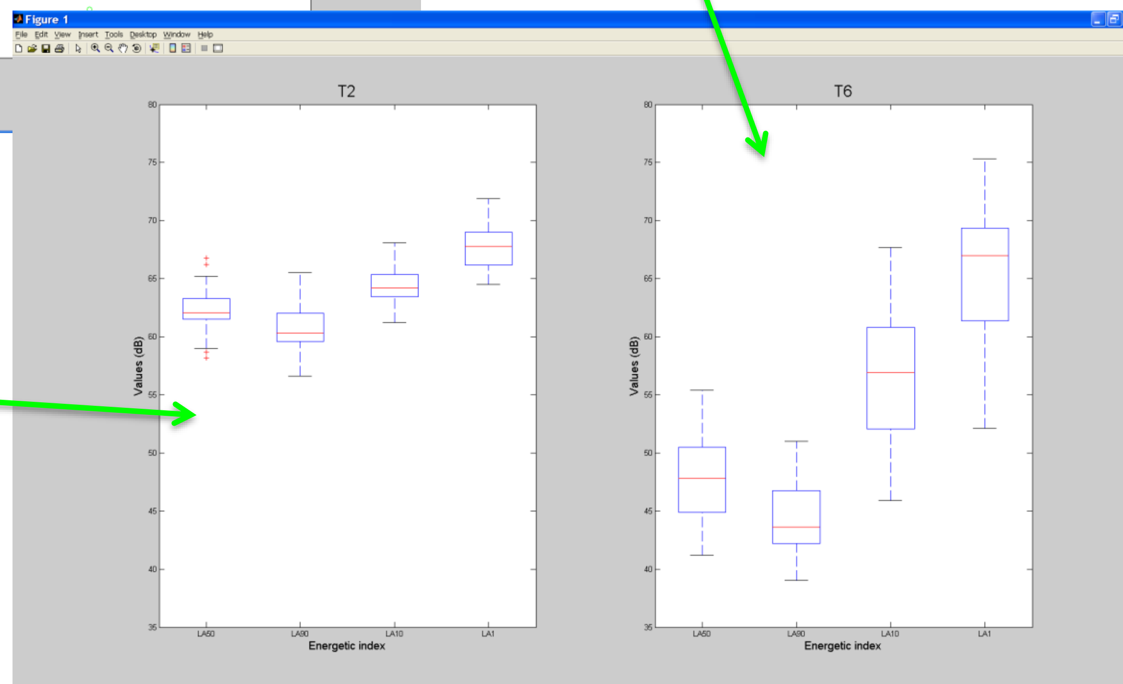
T2_H16_P6
(BF+ roquet

IFSTTAR Be

Physical portraits of studied areas: T2 vs T6

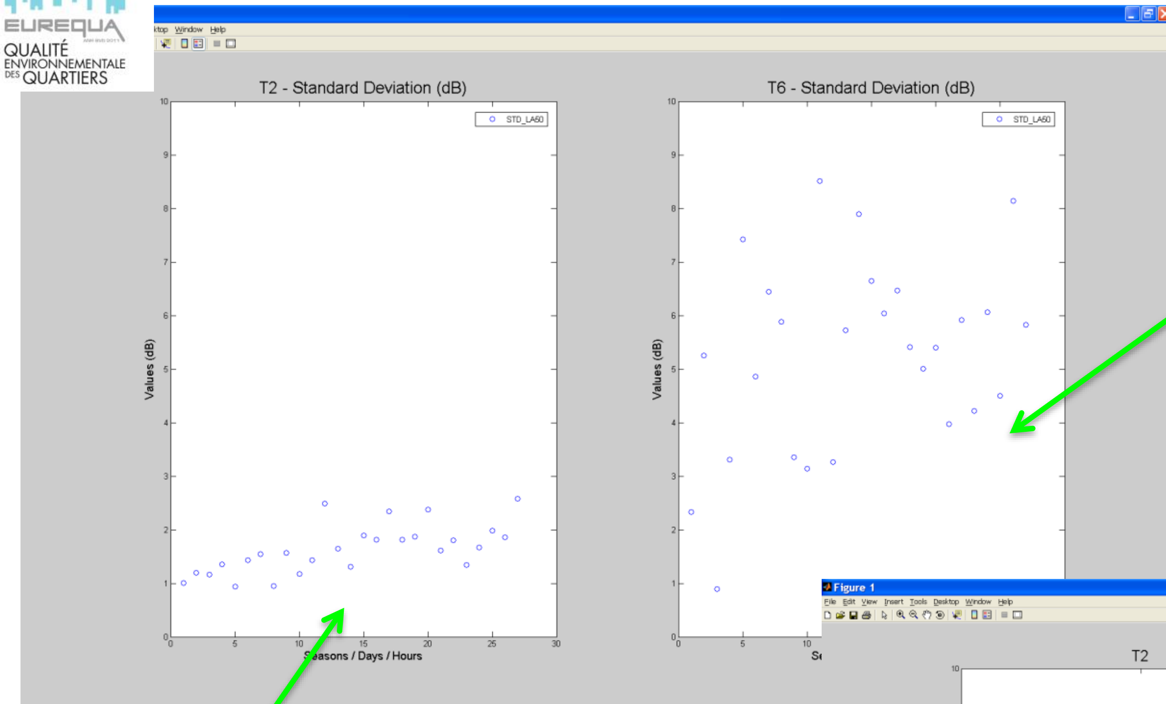


- LA50
- LA90
- LA10
- LA1



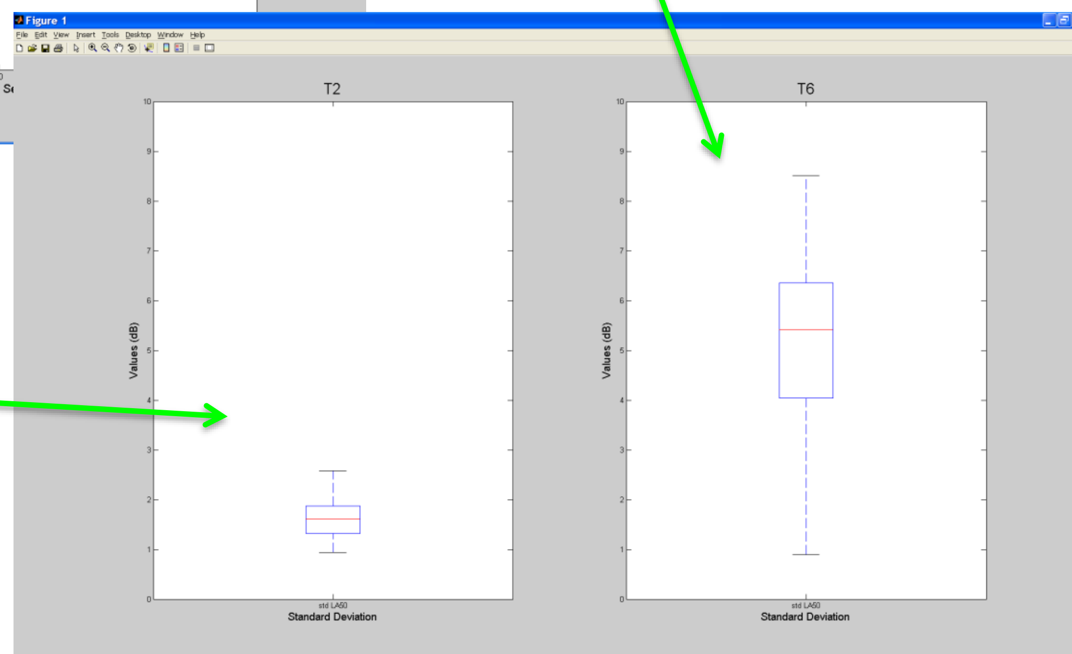
- LA50
- LA90
- LA10
- LA1

Physical portraits of studied areas: T2 vs T6

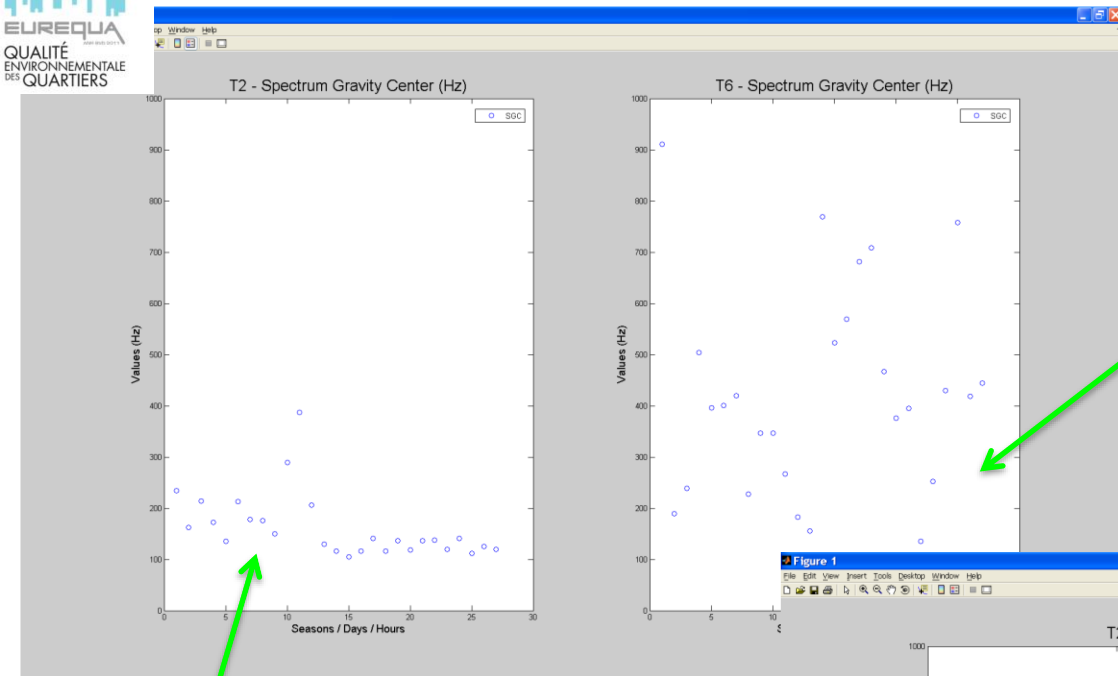


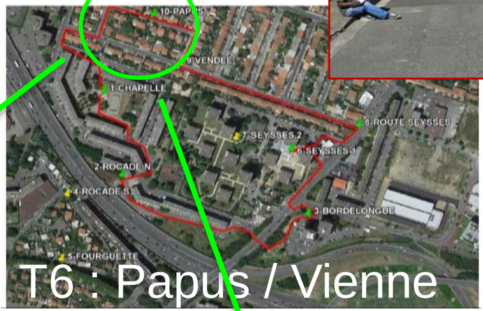
- STD

- STD

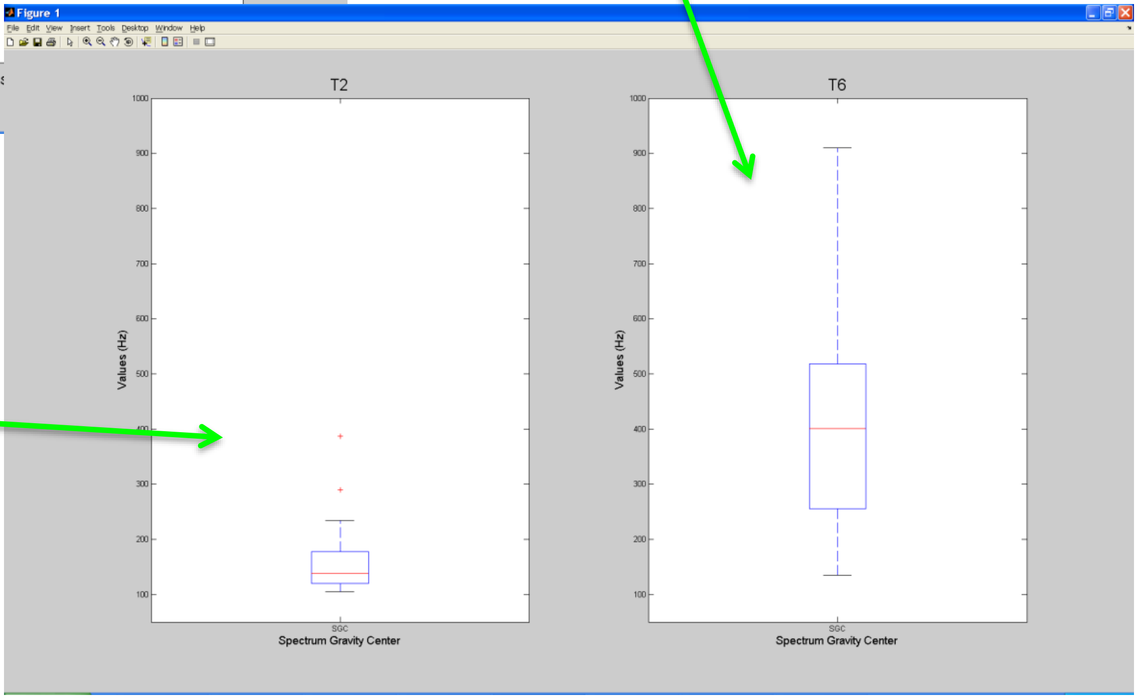


Physical portraits of studied areas: T2 vs T6



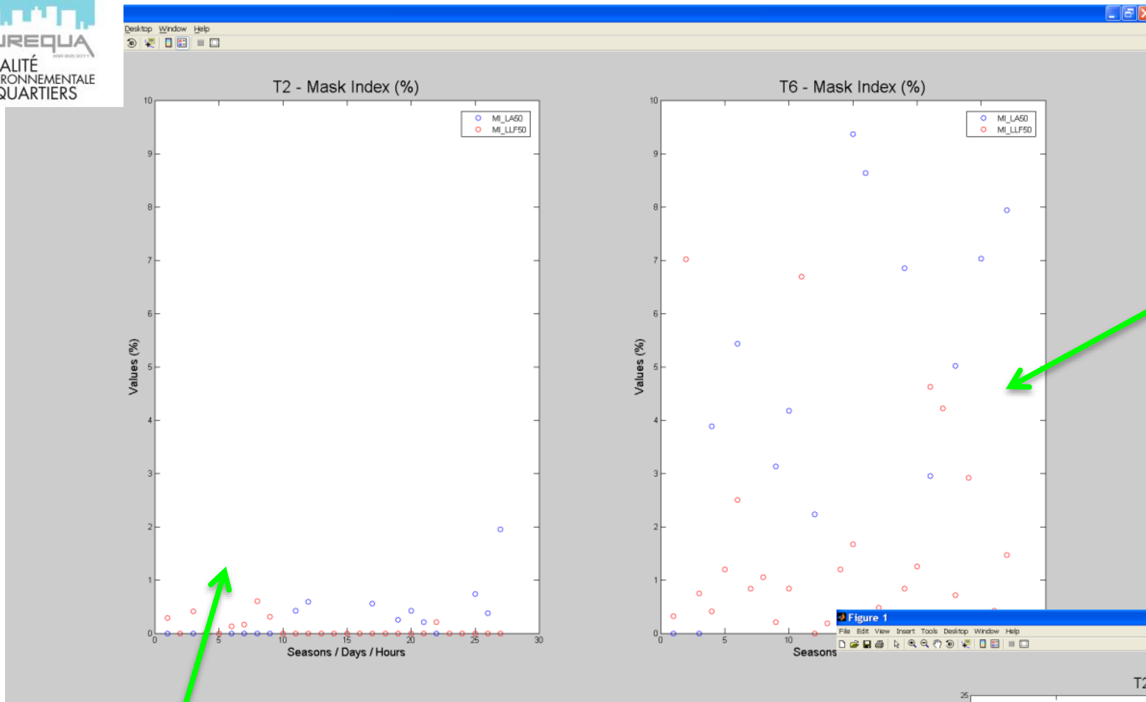


- CGS

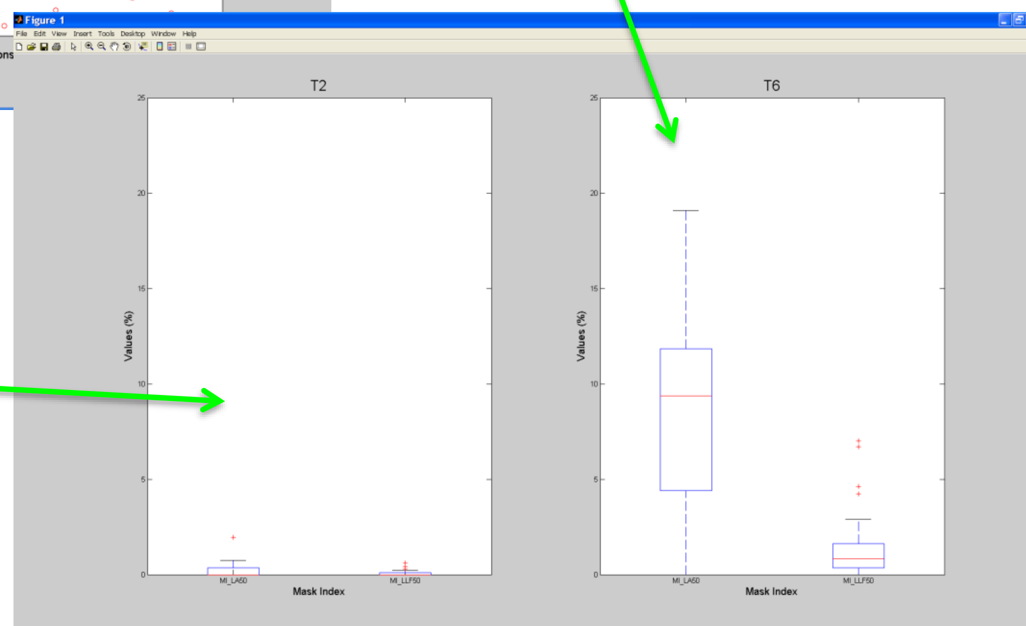


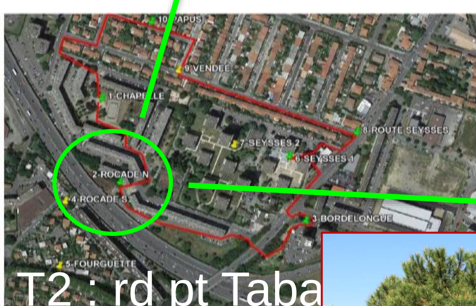
- CGS

Physical portraits of studied areas: T2 vs T6



- MI_LA50
- MI_LLF50



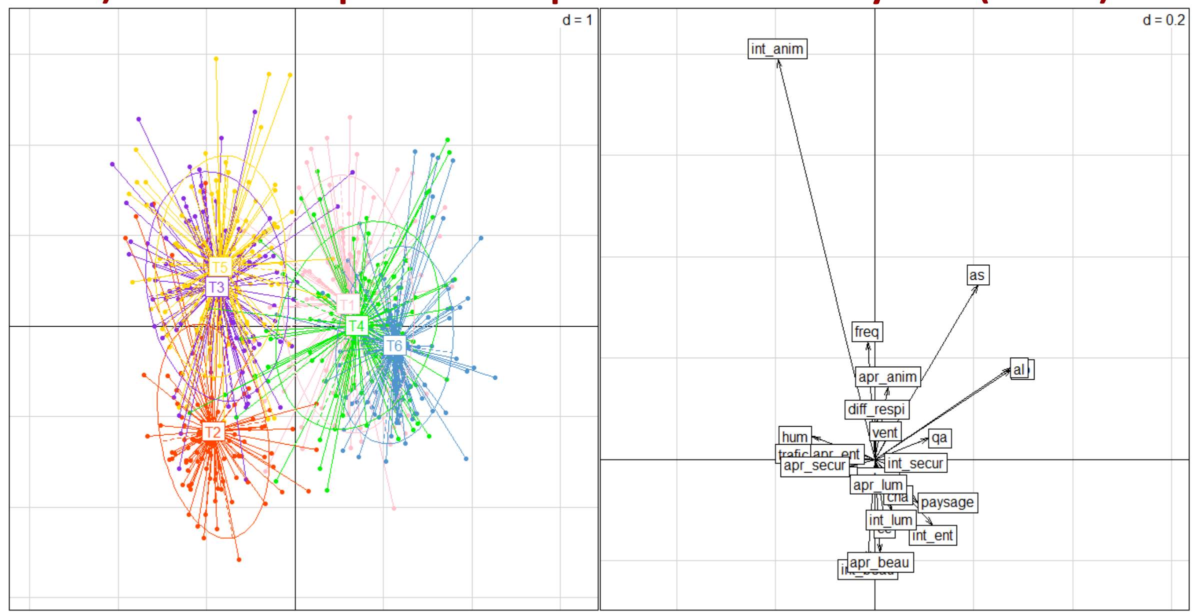


- MI_LA50
- MI_LLF50

Statistical analysis (SHS data + SPI data)

Discriminant Factorial (DFA) & Principal Component Analysis (PCA)

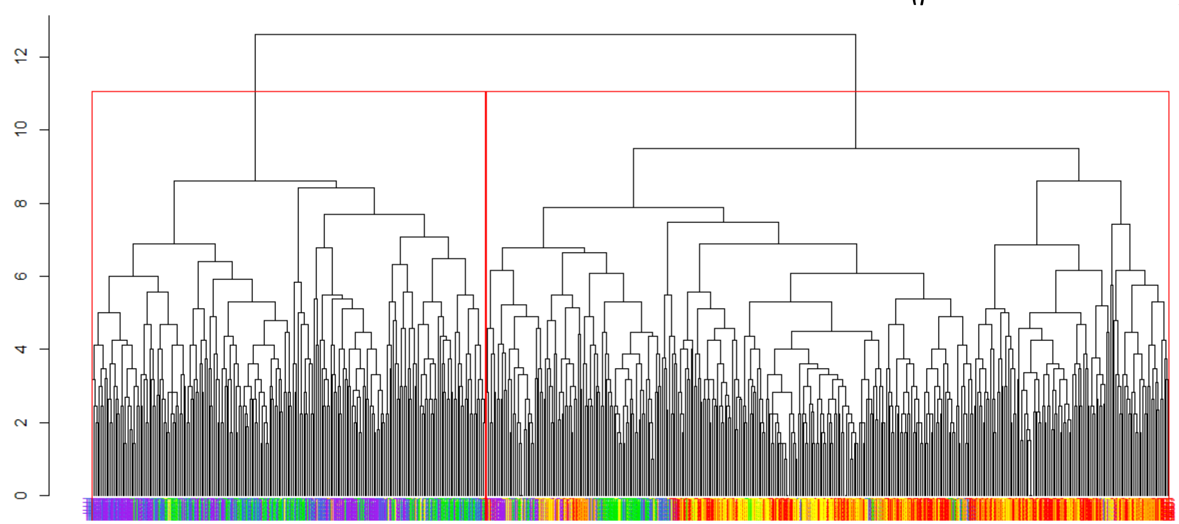
- Sensitive inquiries (SHS)
- *in situ* measurements (SPI)
- Obs: 2 groups
- Work in progress…



Source: A. Amossé (post-doc 2016-2017)

Typological clustering

- Sensitive inquiries (SHS)
- Text analysis + quanti
- « Random forests »
- Obs: 2 groups
- Work in progress…



Co-inertia analysis (climate, all indicators)

NEW

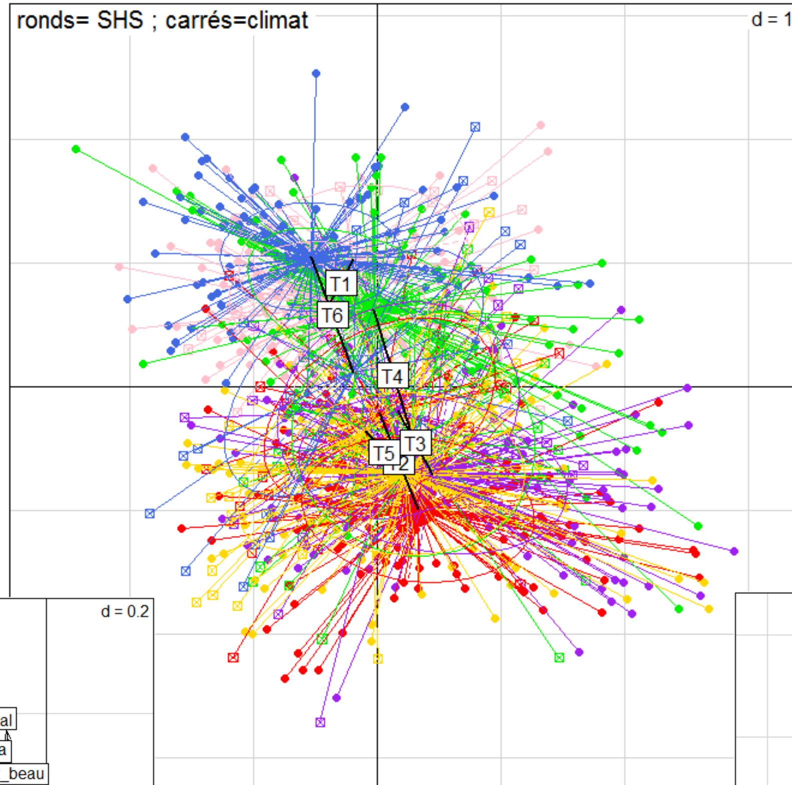
C-I coef. = 0,2159 (season effect)

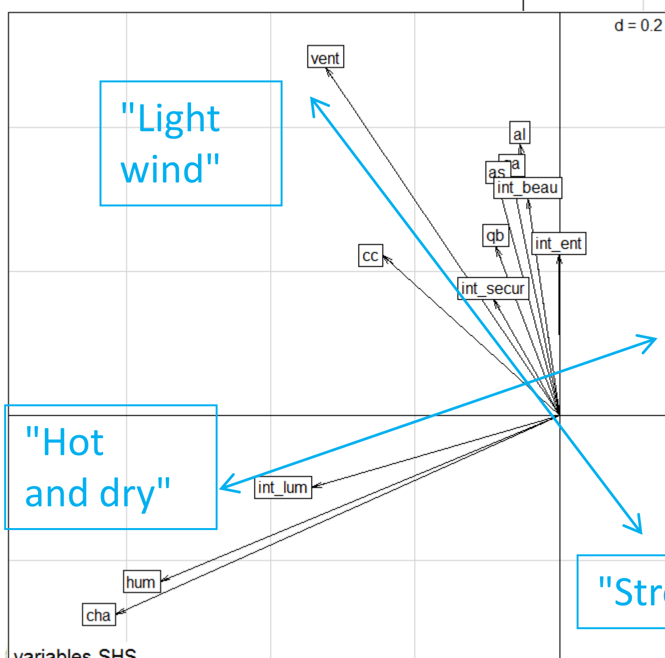
Source: A. Amossé

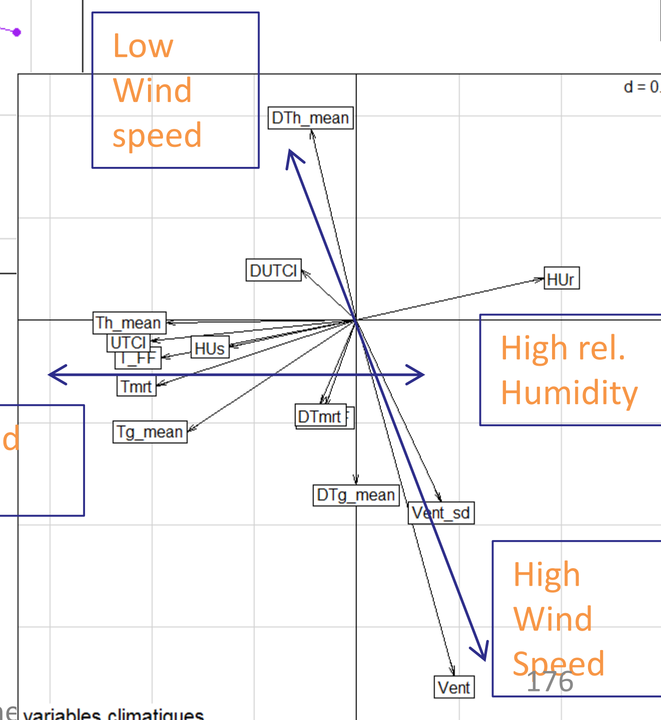
(post-doc 2016-2017)

SHS data (surveys) at stop points Ti (i=1,6)

SPI data (measurements) at stop points Ti (i=1,6)







Co-inertia analysis (acoust., all indicators)

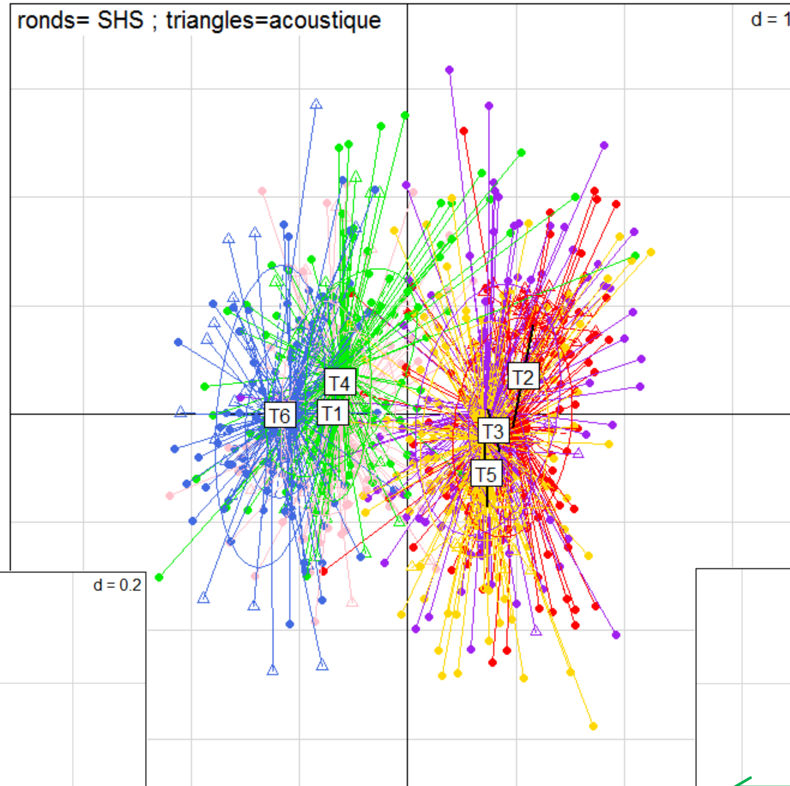
NEW

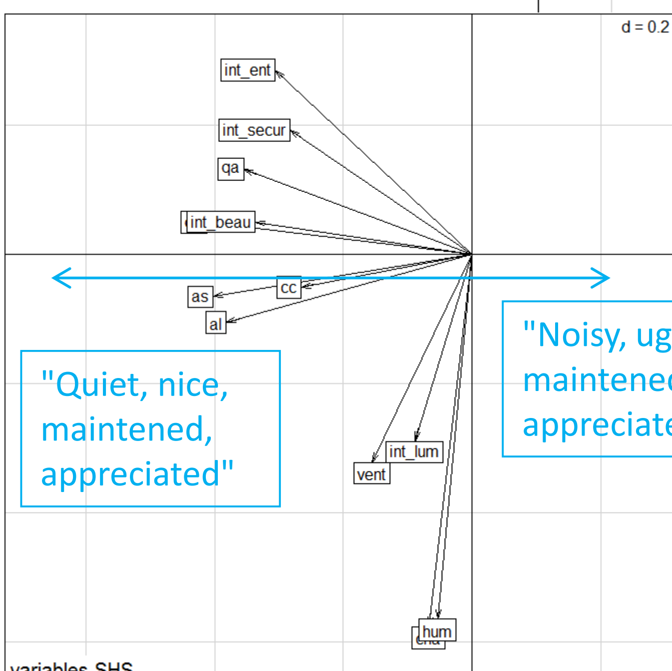
C-I coef. = 0,4716 (2 groups / typo)

Source: A. Amossé
(post-doc 2016-2017)

SHS data (surveys) at stop points Ti (i=1,6)

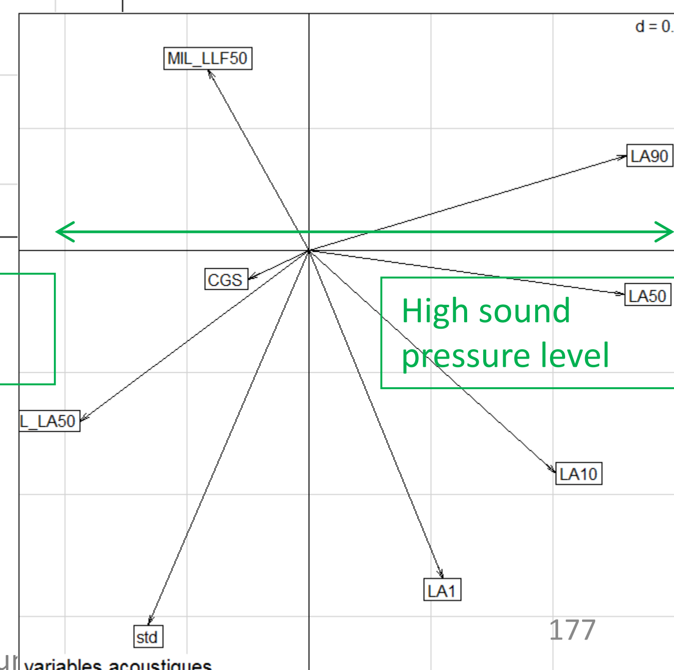
SPI data (measurements) at stop points Ti (i=1,6)





"Quiet, nice, maintened, appreciated"

"Noisy, ugly, not maintened, not appreciated"



Low sound pressure level

High sound pressure level

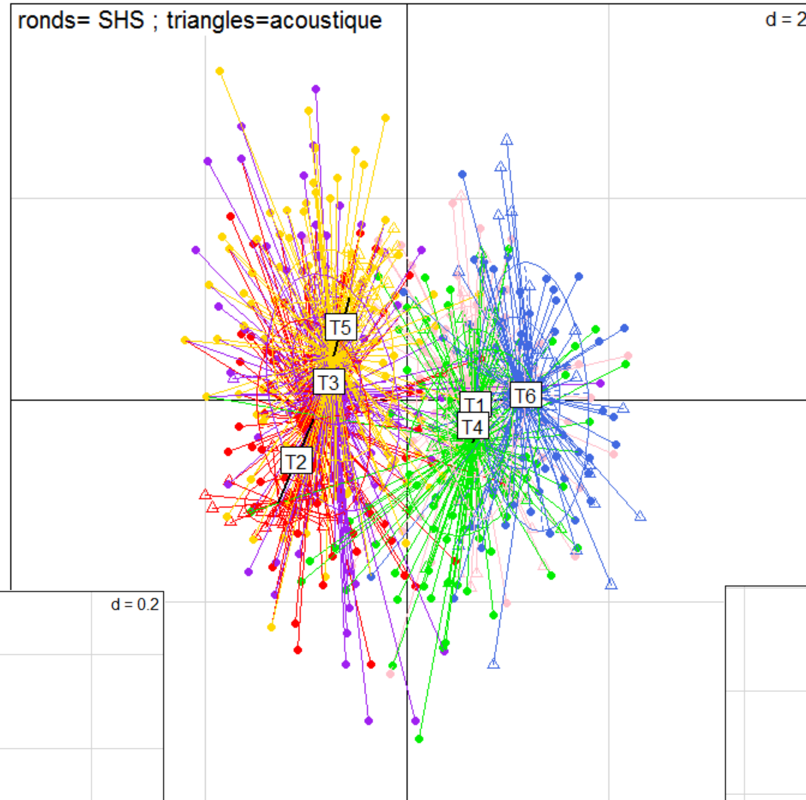
Co-inertia analysis (acoust., best disc.)

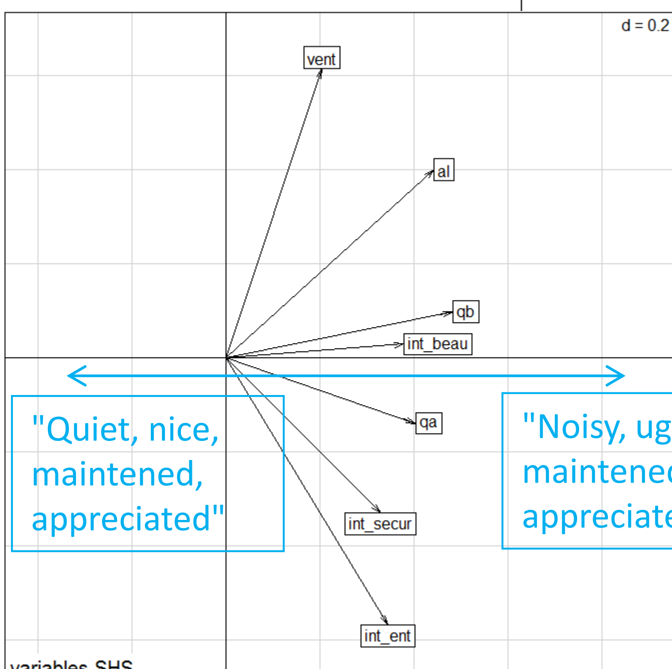
C-I coef. = 0.5078 (> 0.4716)

Source: A. Amossé
(post-doc 2016-2017)

SHS data (surveys) at stop points Ti (i=1,6)

SPI data (measurements) at stop points Ti (i=1,6)





"Quiet, nice, maintened, appreciated"

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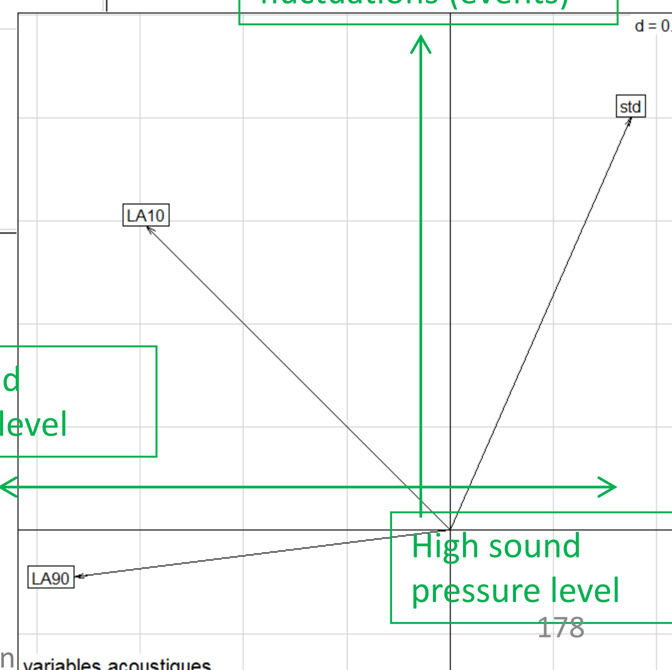


More sound pressure fluctuations (events)

Low sound pressure level

High sound pressure level

Transdisciplinary and participatory process: Feedback and outlooks

- Feedback workshops and *scenarii* construction for urban planning
  - Together with inhabitants, district users, local actors, stakeholders and elected representatives
  - At Paris, Marseille and Toulouse (F)

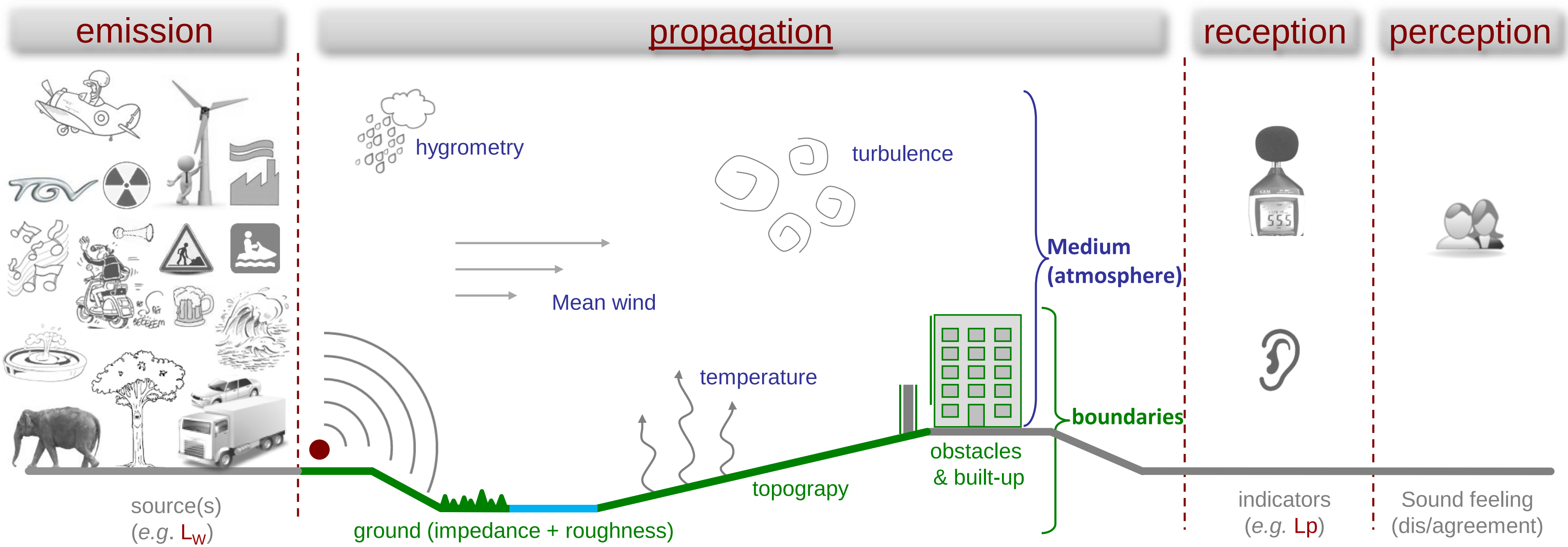




Sources : I. Richard & J. Lafille

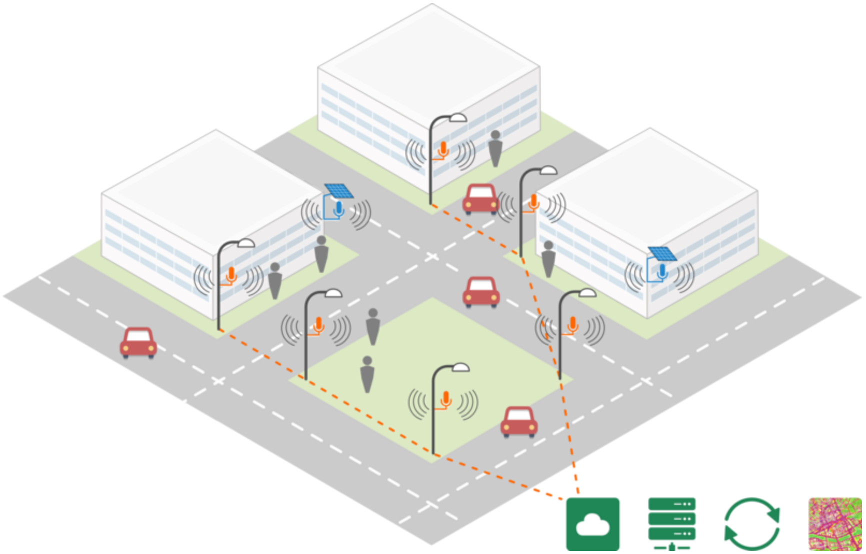
- Numerical simulations for new *scenarii*: under progress…
- <u>Transdisciplinary</u>
  = <u>pluri</u> or <u>multidisciplinary</u> (1960-1970) + interconnections
  = <u>interdisciplinary</u> *ex ante* (at the early beginning of a project)
  = decompartmentalisation and knownledge porosity
  = richness of scientific – and human – exchanges
  = also time consuming, sometimes ☺
- From the research methodology to the development of an executive tool for action plans and environmental requalification in urban medium
  - Recognition of plurality and legitimity of « expert voices » and opinions: inhabitants, users, professionals, politicians, scientists, etc.
  - Generecity *vs* Adaptability to the context of *scenarii* implementation
  - A tool/method for operational actors, without resorting to researchers

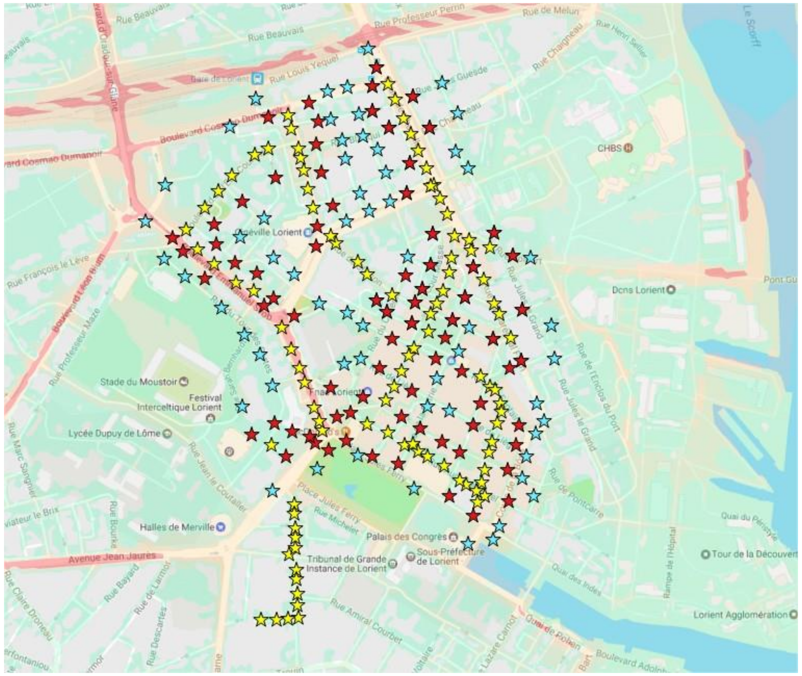
CENSE (2017-2020, under progress…)



CENSE (2017-2020, under progress…)

http://cense.ifsttar.fr

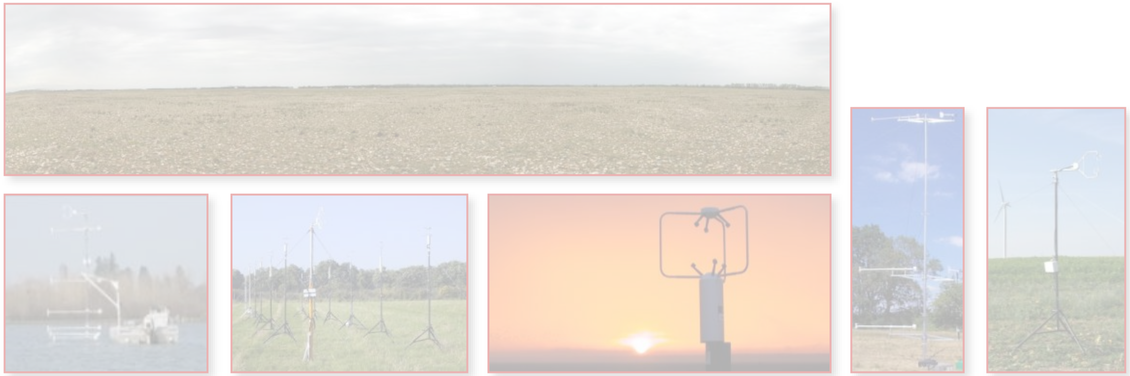




Contents

> **Foreword**
- Noise emission
- *Noise propagation : influence of boundaries characteristics and medium (atmosphere / micrometeo) conditions*
- Noise reception/perception

> **Examples in *open field*** (without obstacles, flat or complex topography)
- Laon_1999
- Harmonoise_2002-2004
- Lannemezan_2005
- Sonic_2007
- LTMS_2002-2007
- Fouché_2013
- Ifsttar_2011
- PhD Thesis O. Faure (2014)
- PhD Thesis B. Kayser (2017) >> LRSP
- MIAME prototype (impedance measurement)



> **Examples in *urban medium*** (multiple sound sources + obstacles >> « diffuse field »)
- Tours_2002
- EM2PAU_2012
- VegDUD_2014
- EUREQUA_2016
- CENSE_2018

> **Conclusion and outlooks**
- Variability (deterministic) + uncertainty (stochastic)
- SPL dispersion in space
- SPL dispersion in time
- Other indicators (EDT, TR, etc.)
- Influent parameters (observables) for outdoor sound propagation
- Input data for numerical predictions
- >> D. Écotière lesson on “Uncertainties and variability”…

Synthesis

Input data : uncertainties and variability

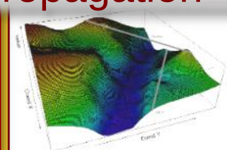
emission

Sound sources

propagation

Roughness

Impedance

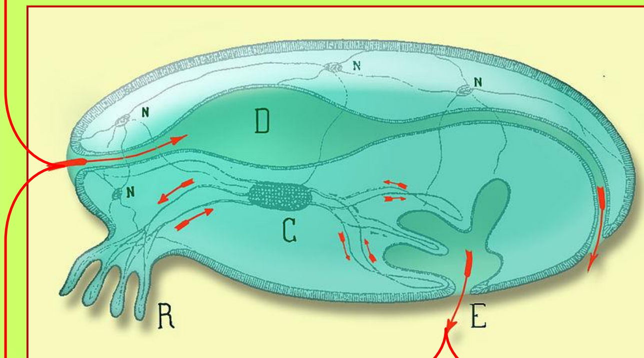


Topography

Built-up

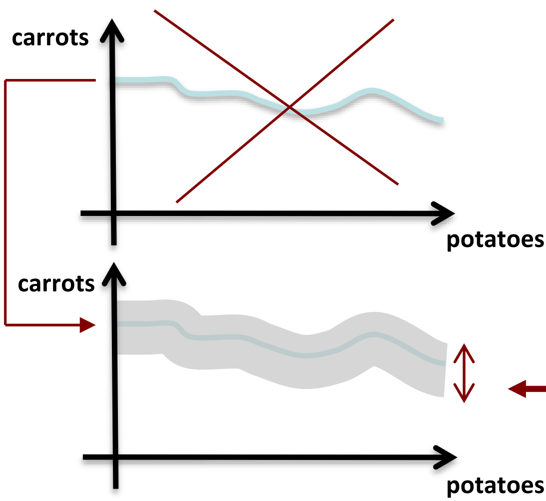
Atmosphere

propagation model : hypothesis, approximations, numerical schemes



output data : uncertainties on indicators… and on decisions!

reception perception



- dispersion (EXP <u>and</u> NUM) of *indicators* values
- notions of *uncertainties* and *risk*, *e.g*. *via* PDF
- Physico-probabilistic approaches (Bayes)
- Transfer to standards, rules and reglementations

references

Webography

Smartphone app. (android) : http://noise-planet.org/fr/noisecapture.html 
OrbisGIS : http:www.orbisgis.org
NoiseModelling : http://noise-planet.org/fr/noisemodelling.html
I-Simpa : http://i-simpa.ifsttar.fr/
Code_TYMPAN : http://innovation.edf.com/recherche-et-communaute-scientifique/logiciels/code-tympan-94425.html
LTMS : http://ltms2002-2007.ifsttar.fr/
SFA_GABE : http://sfa.asso.fr/fr/activites-gssr/le-groupe--acoustique-du-batiment-et-de-l-environnement-gabe

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only 36€ ! → 

Thank you for your attention

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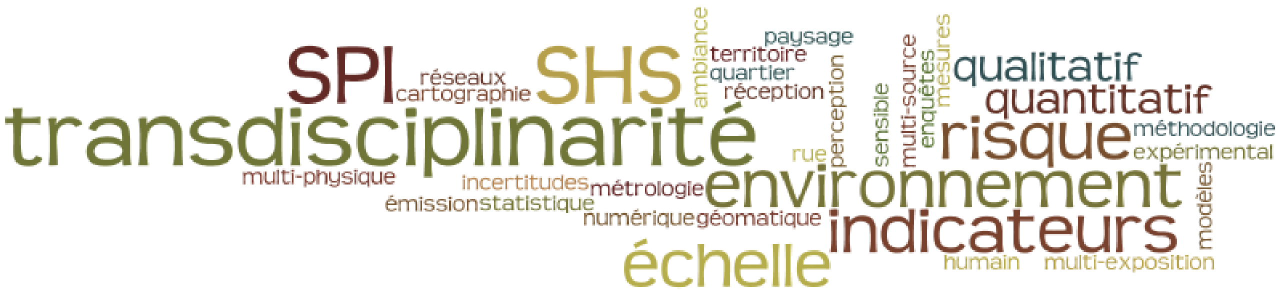

« La prévalence disciplinaire, séparatrice, nous fait perdre l’aptitude à relier, l’aptitude à contextualiser »

E. Morin
Sept. 2014