SMOKE LAYER / WATER SPRAY INTERACTION: IMPACT ON VISIBILITY AND THERMAL CONDITIONS

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Context

French strategy promotes **self-evacuation** of people. Then, it aims at making **fire-fighting** conditions better and limiting **fire propagation**

French building standard allows sprinkler systems in some public buildings and in particular cases

What about water mist systems?

Context

What about water mist systems?

French building standard is evolving:

an article to be published soon

4/ Modifications du règlement de sécurité :
4-1 : Proposition de modification de l'article MS 26

La proposition suivante de rédaction de l'article MS 26 est approuvée.
Le besoin de solliciter la CCS dans le cadre de l'application du §5 de l'article MS 26 doit pouvoir être identifié dés la réception du dossier au moyen de la partie « dérogation » des imprimés CERFA. et le secrétariat de la CCS devra être saisi sans délai.

Article MS 26 Installation d'extinction automatique par brouillard d'eau.

§ 1. Une installation d'extinction automatique par brouillard d'eau peut être mise en place à titre volontaire, pour la défense contre l'incendie dans tout ou partie d'un établissement.

§ 2. La mise en place d'une installation de brouillard d'eau dans les locaux techniques électriques recevant des installations de haute tension tient compte des risques de chocs électriques pour les personnes.

§ 3. L'aménagement et l'exploitation des locaux protégés ne doivent pas s'opposer au fonctionnement dans les meilleurs délais et à pleine efficacité du système.

§ 4. Un système d'extinction automatique par brouillard d'eau doit avoir satisfait aux essais de l'annexe A de la spécification technique CEN TS 14972 (Installations fixes de lutte contre l'incendie – Systèmes à brouillard d'eau – Conception et installation – Juin 2011) et être réalisé par des entreprises spécialisées.

§5. Dans le cas de l'examen d'un dossier où la technologie du brouillard d'eau est présentée comme une mesure compensatoire, en application des dispositions de l'article R123-13 du Code de la construction et de l'habitation, il appartient à la commission centrale de sécurité d'apprécier, au cas par cas, si la compensation est suffisante vis-à-vis de l'atténuation demandée.

But many questions has been raised

- What is their performance ?
- What are the conditions for people and fire-fighters?
- Same questions but integrated to other systems (ventilation systems)?

Objectives

Our research focuses on **water spray/smoke layer interaction**

- To question the notion of stratification
- To be able to measure opacity in extreme conditions
- To estimate and foresee visibility conditions

and also,

- To improve our understanding of the involved phenomena and to quantify them

with different water spray systems

Lemta Danfoss INSTITUT P' CSTB le futur en construction

Objectives

Our research focuses on **water spray/smoke layer interaction**

- To question the notion of stratification
- To be able to measure opacity in such conditions
- To estimate and foresee visibility conditions **Why?**

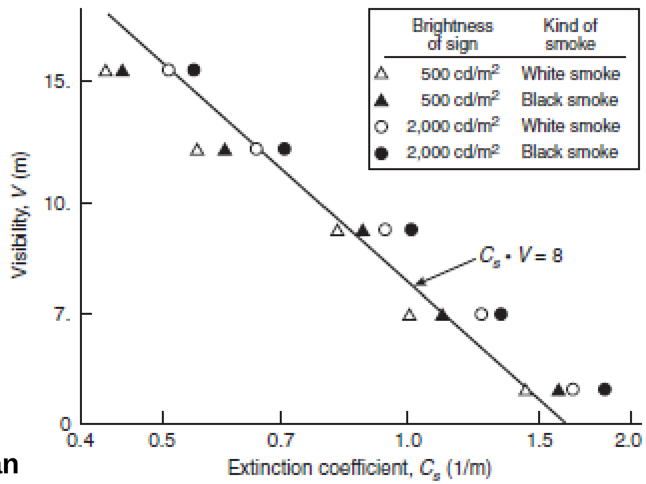


Figure 2-4.2. *Relation between the visibility of self-illuminated signs at the obscurity threshold and smoke density (extinction coefficient).*

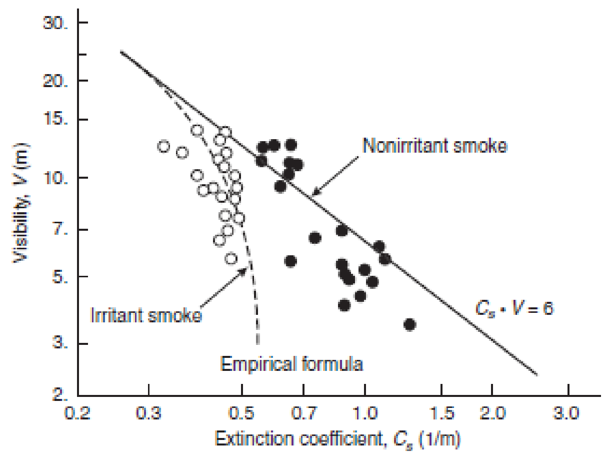


Figure 2-4.3. *Visibility of the FIRE EXIT sign (signs of the type used before 1982) at the legible threshold of the words in irritant and nonirritant smoke.*

Smoke with droplets in suspension is a participating medium with absorption AND scattering phenomena

SFPE Handbook Section 2 Chapter 4 "Visibility and Human Behavior in Fire Smoke" Tadahisa Jin

Approach

By focusing on water spray/ smoke layer interaction

Test campaign
- Repetability
- Measurement uncertainties

To assess its realism

To understand 3D phenomena

Input data

Development of a tool to render visibility conditions

Input data

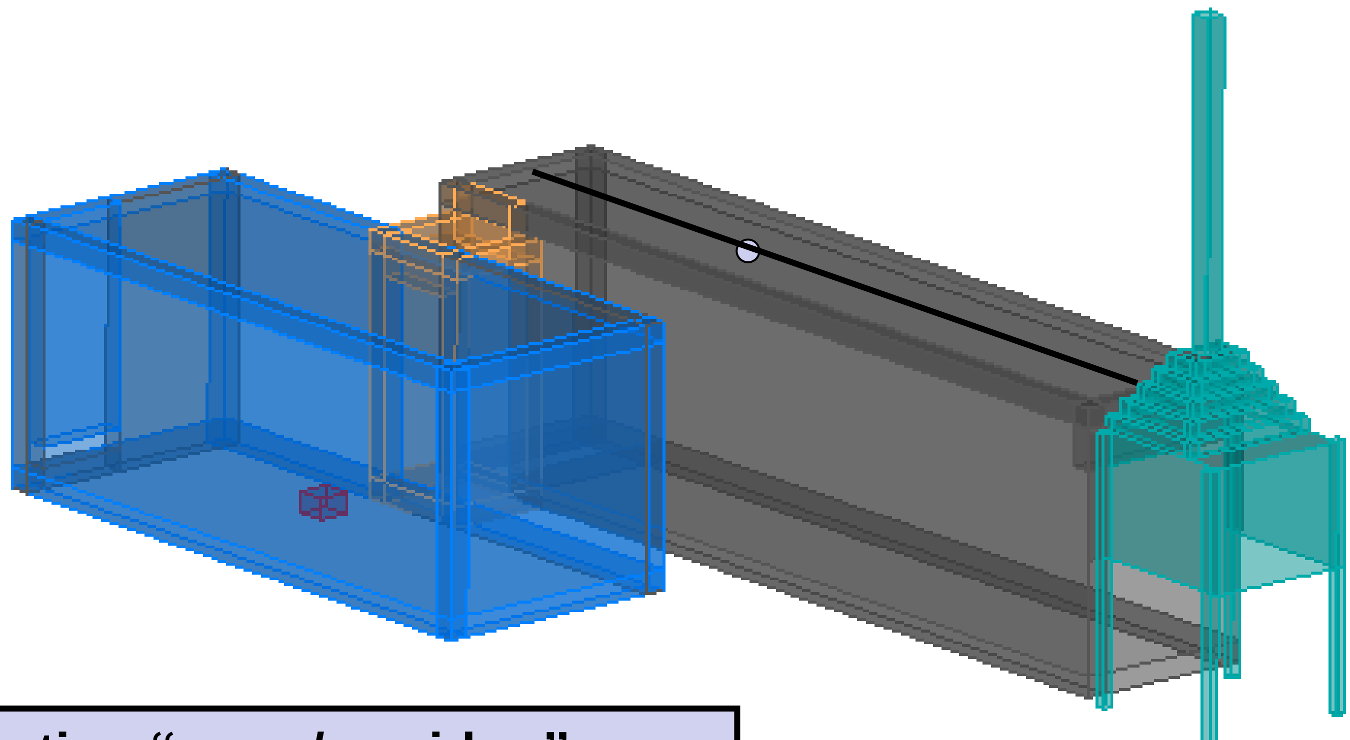
Computational reconstruction
- To assess codes
- To quantify the phenomena
- To get certain quantities
- To evaluate sensitivity

To provide a new vizualisation of the results

FDS developed by NIST and VTT

le futur en construction

Description of the configuration



Configuration "room/corridor "

- Room: 12 m² surface area and 2.15m high
- Corridor: 9m long and 2.35m high
- No mechanic ventilation system (until now)

➡ To focus on water spray/ smoke layer interaction

Description of the configuration

Context
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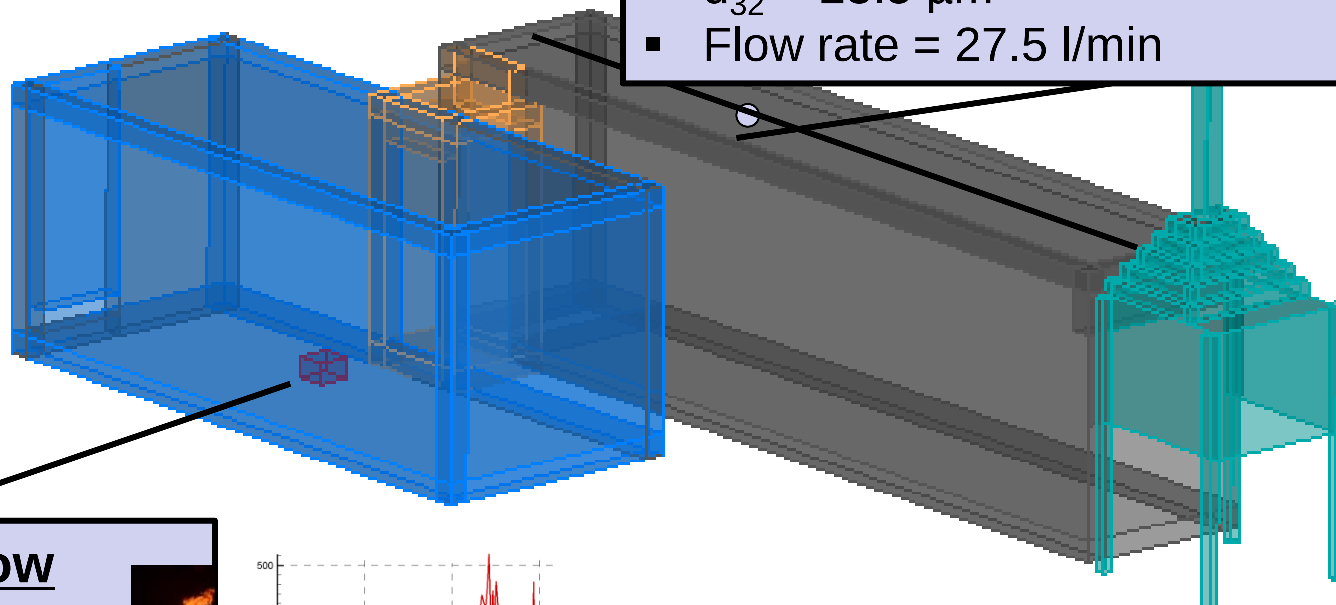
Approach
Description of the configuration
Main results
Conclusion

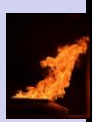


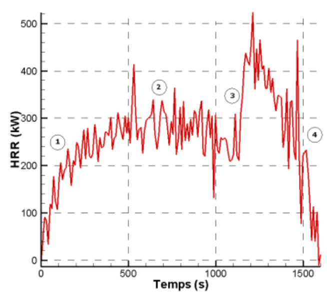
<u>Water spray system : a HP until now</u>

- Operating pressure around 110 bars
- d_{32} = 23.5 µm
- Flow rate = 27.5 l/min

<u>Fire load until now</u>

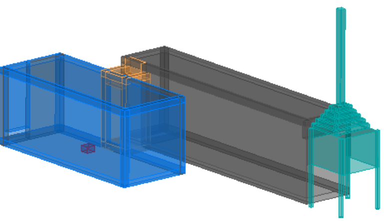
- 0.09 m² heptane pool
- To limit uncertainties
- Surface = 0.09 m²
- HRR ≈ 275 kW





➡ To focus on water spray/ smoke layer interaction

Instrumentation

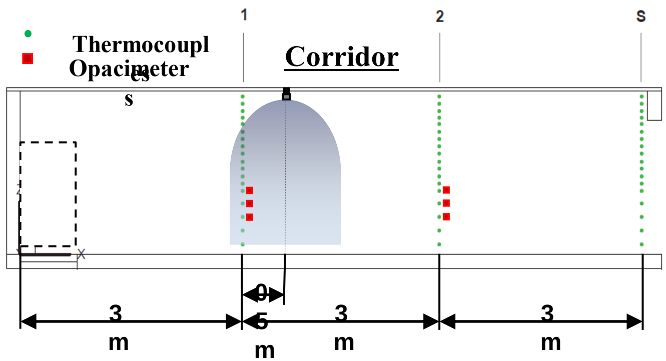


Description of the configuration

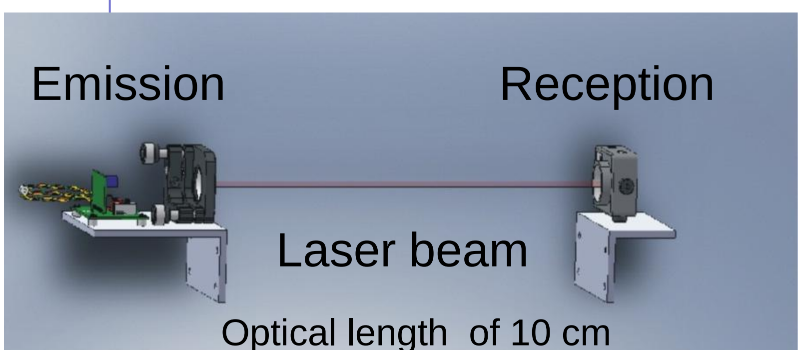
Main results

Conclusion

- **HRR** by monitoring MLR
- **Gas temperature** along 4 Tc trees
- **Opacity** along 2 trees



$$\text{Transmissivity} = \frac{\Phi \text{ received during test}}{\Phi \text{ received before test}}$$

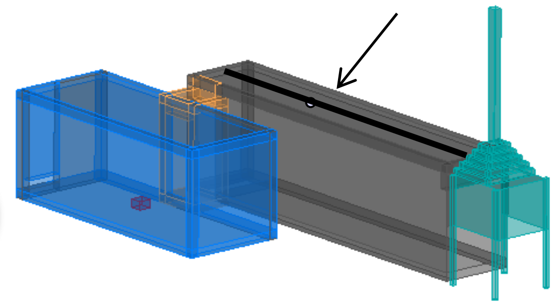


Problem ! Opacimeters cannot be used above 50˚C

➡ We are currently designing a opacimetry system which can work under high temperatures

Main results

Test campaign
- Repetability
- Measurement uncertainties

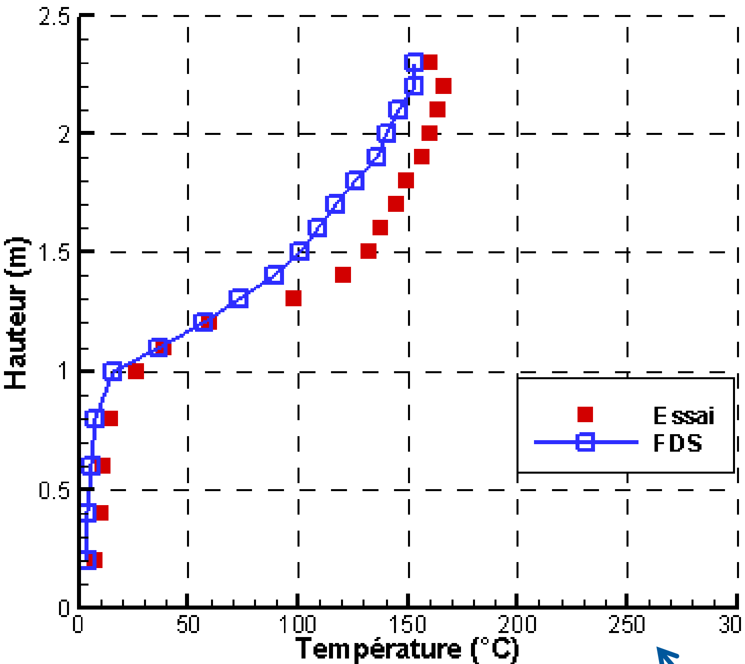


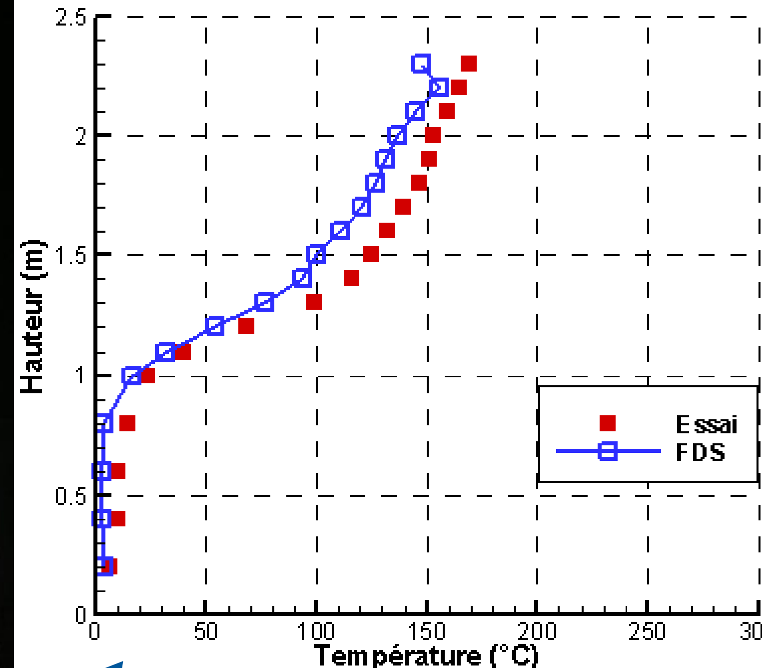
2 tests :
- one without water mist
- one with a nozzle manually activated at 360 s

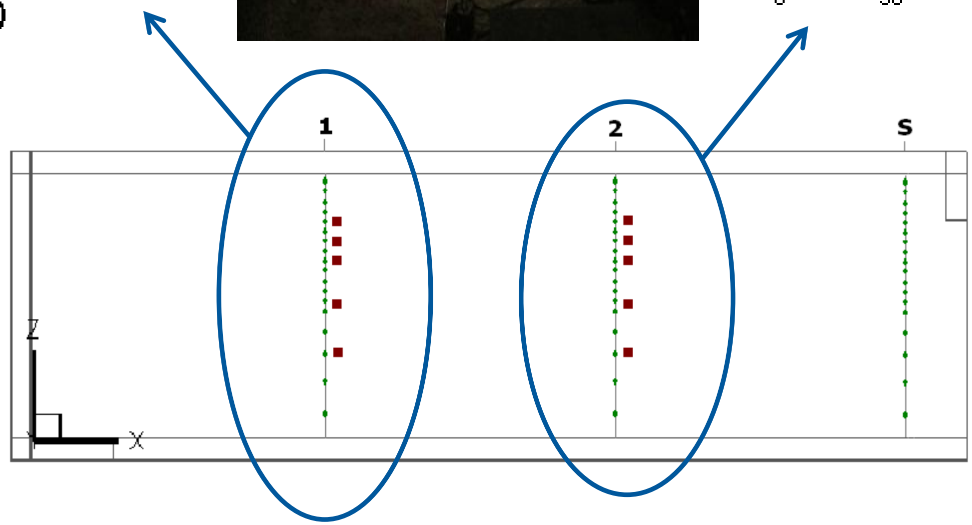
Development of a tool to render visibility conditions

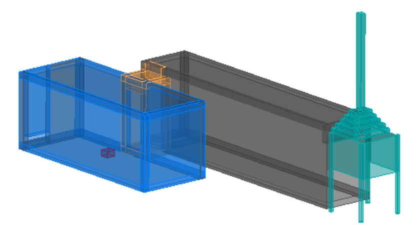
Computational reconstruction
- To assess codes
- To quantify the phenomena
- To get certain quantities
- To evaluate sensitivity

Main results, without mist

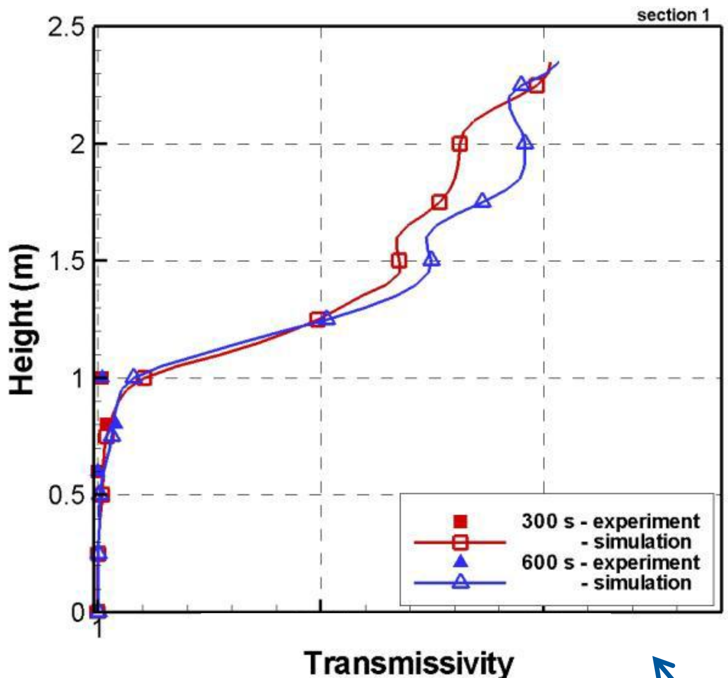


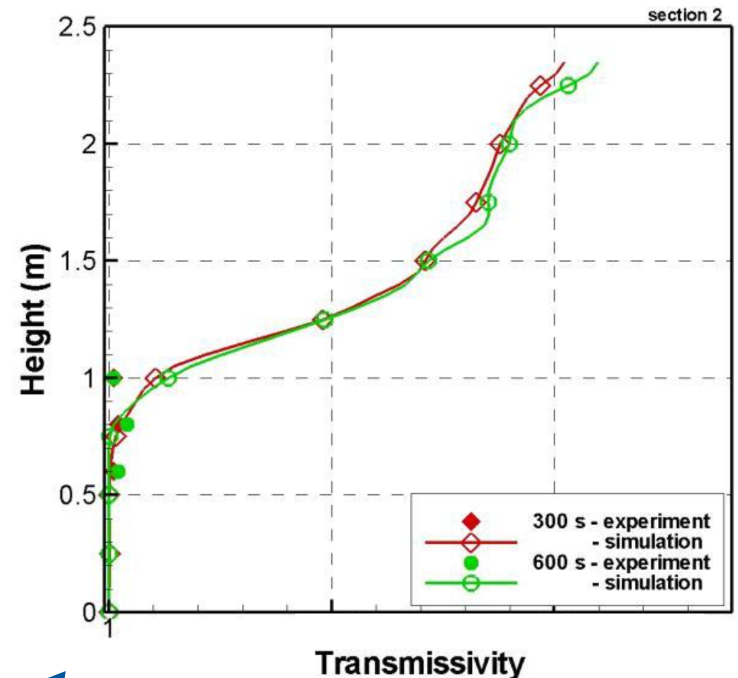






Main results, without mist

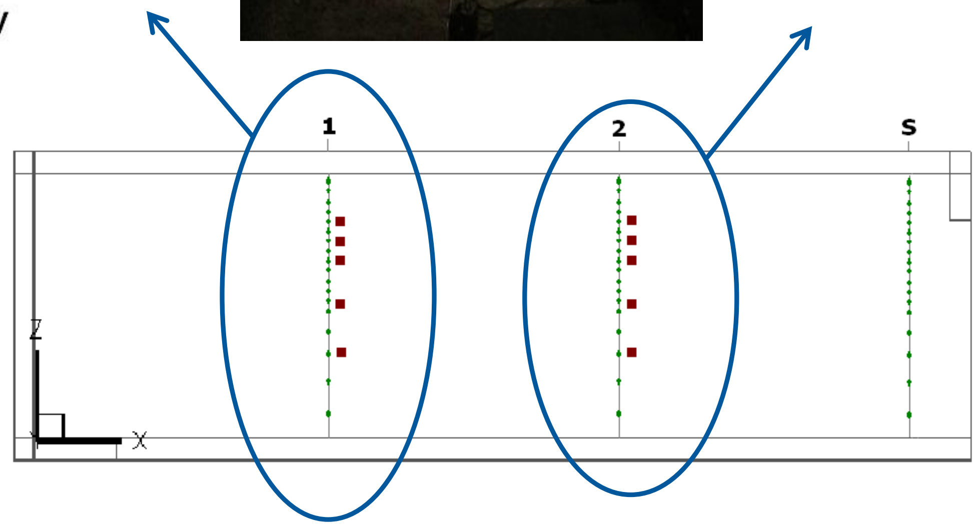


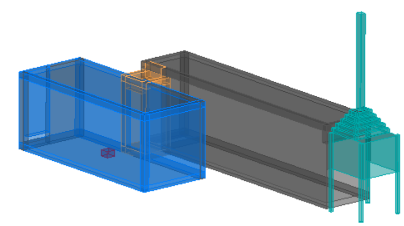


$$\tau = e^{\int_0^L \kappa.dy} = e^{\sum_i \kappa_i.\Delta y}$$

$$\kappa = \frac{5.5 \times f_v}{\lambda}$$

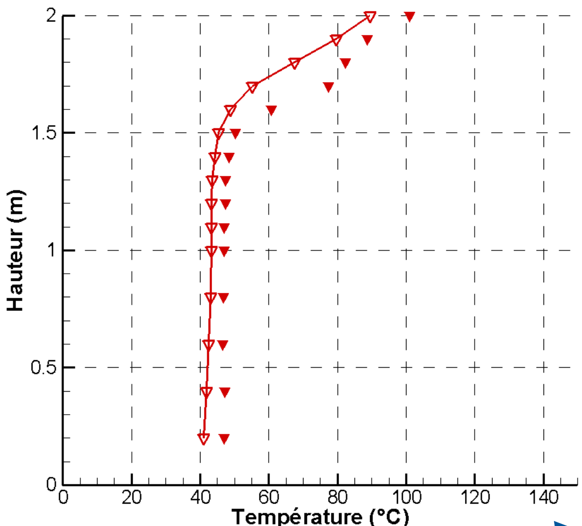
Solovjov and Webb

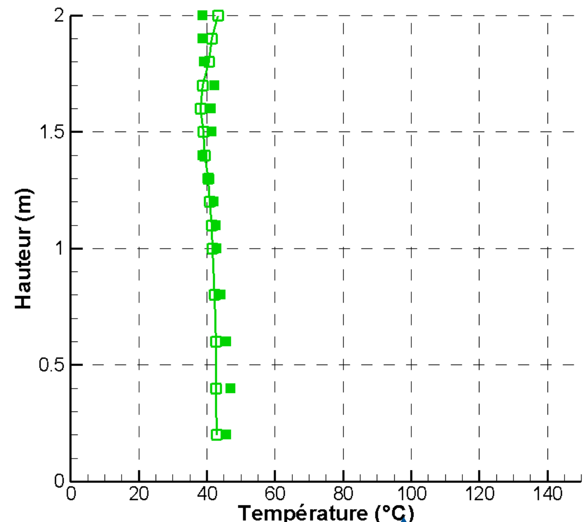


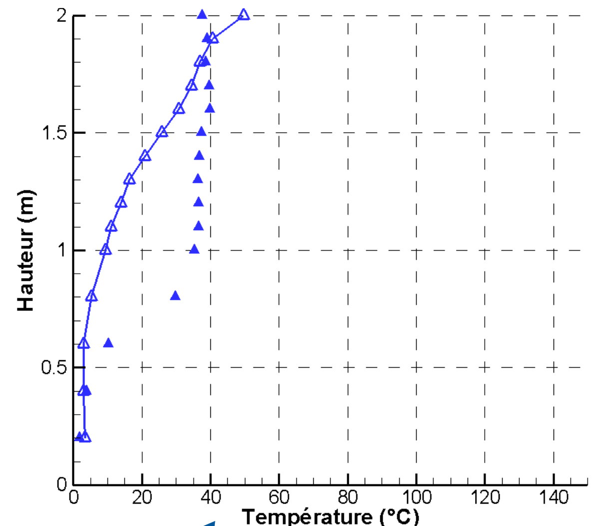


Main results, after mist activation

2.5m downstream the mist nozzle
Measurement
FDS predictions

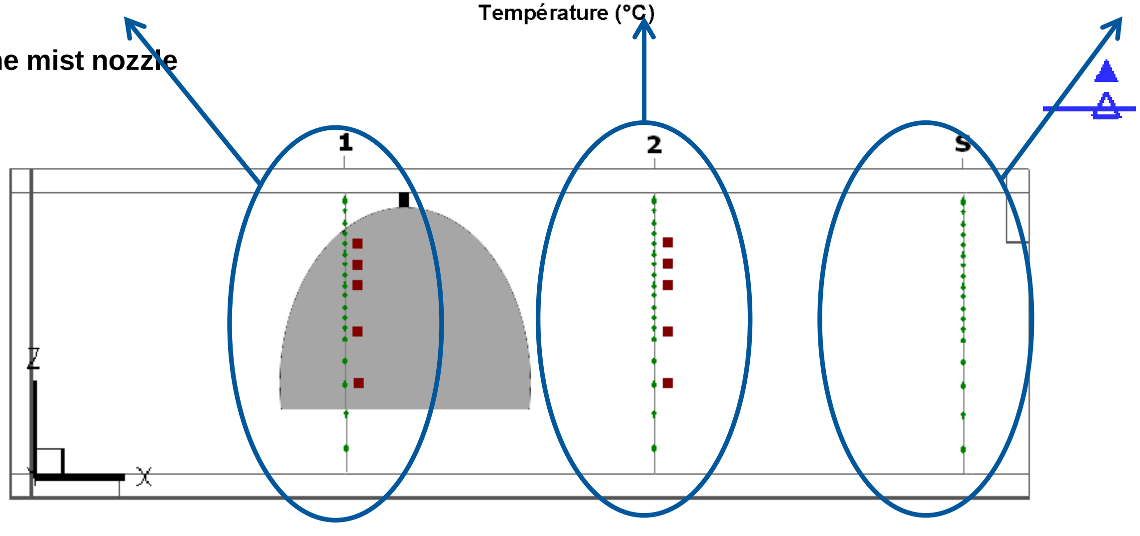


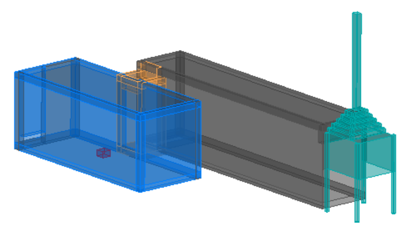




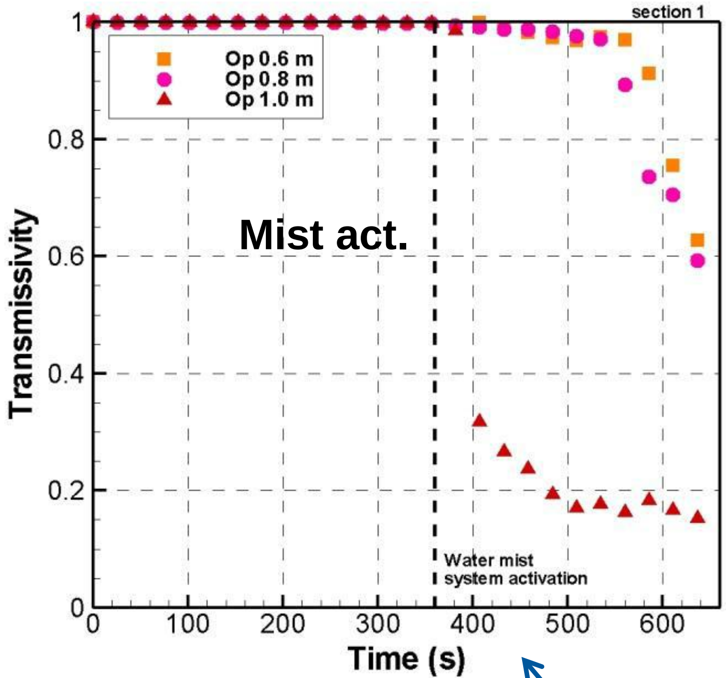
0.5m upstream the mist nozzle
Measurement
FDS predictions

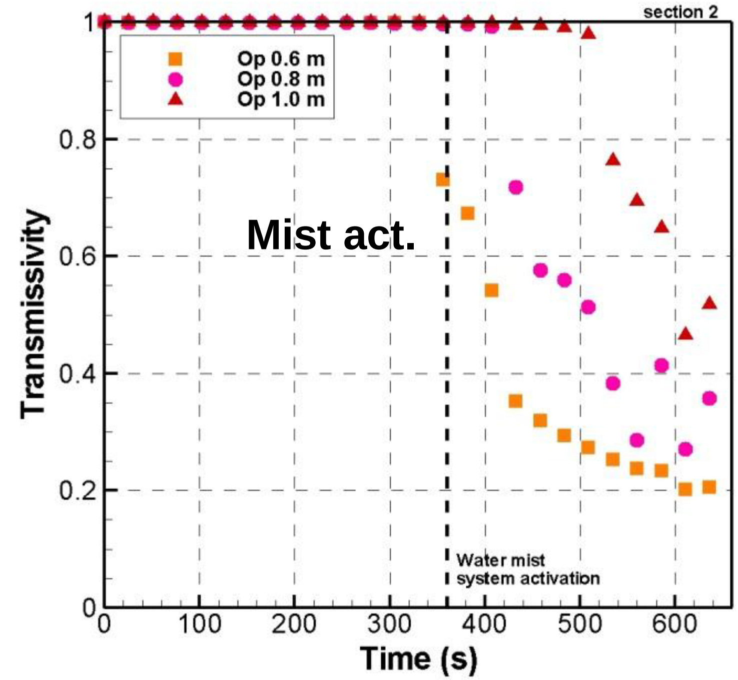
5.5m downstream the mist nozzle
Measurement
FDS predictions

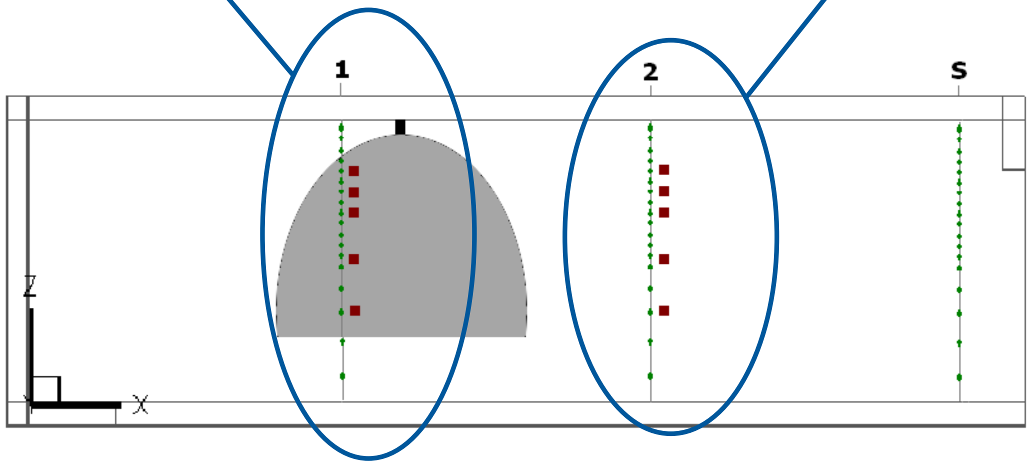


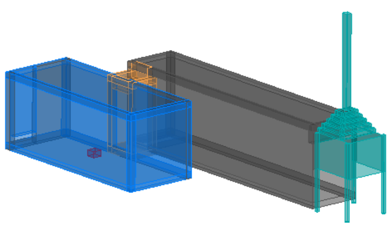


Main results, after mist activation

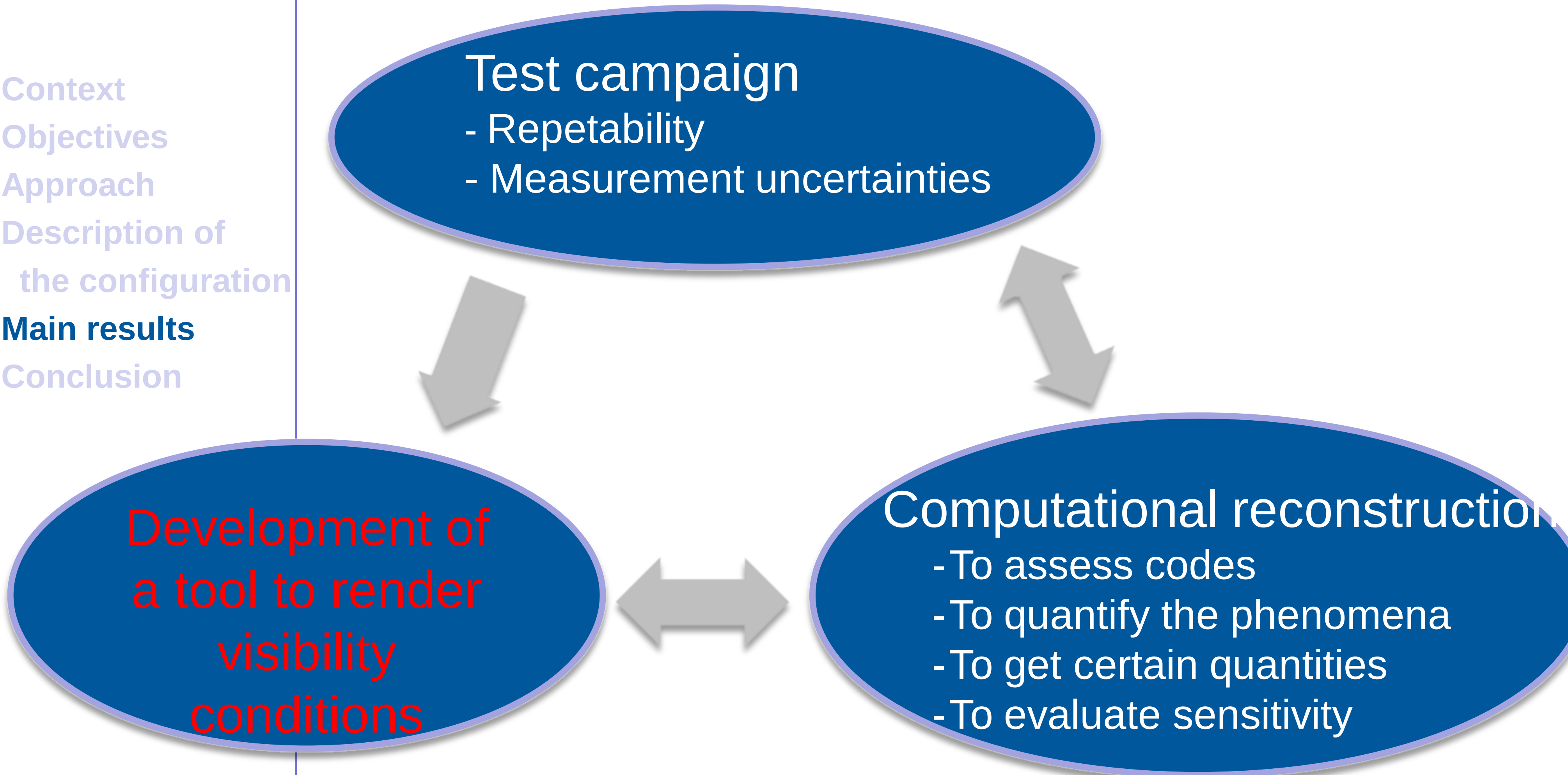








Main results



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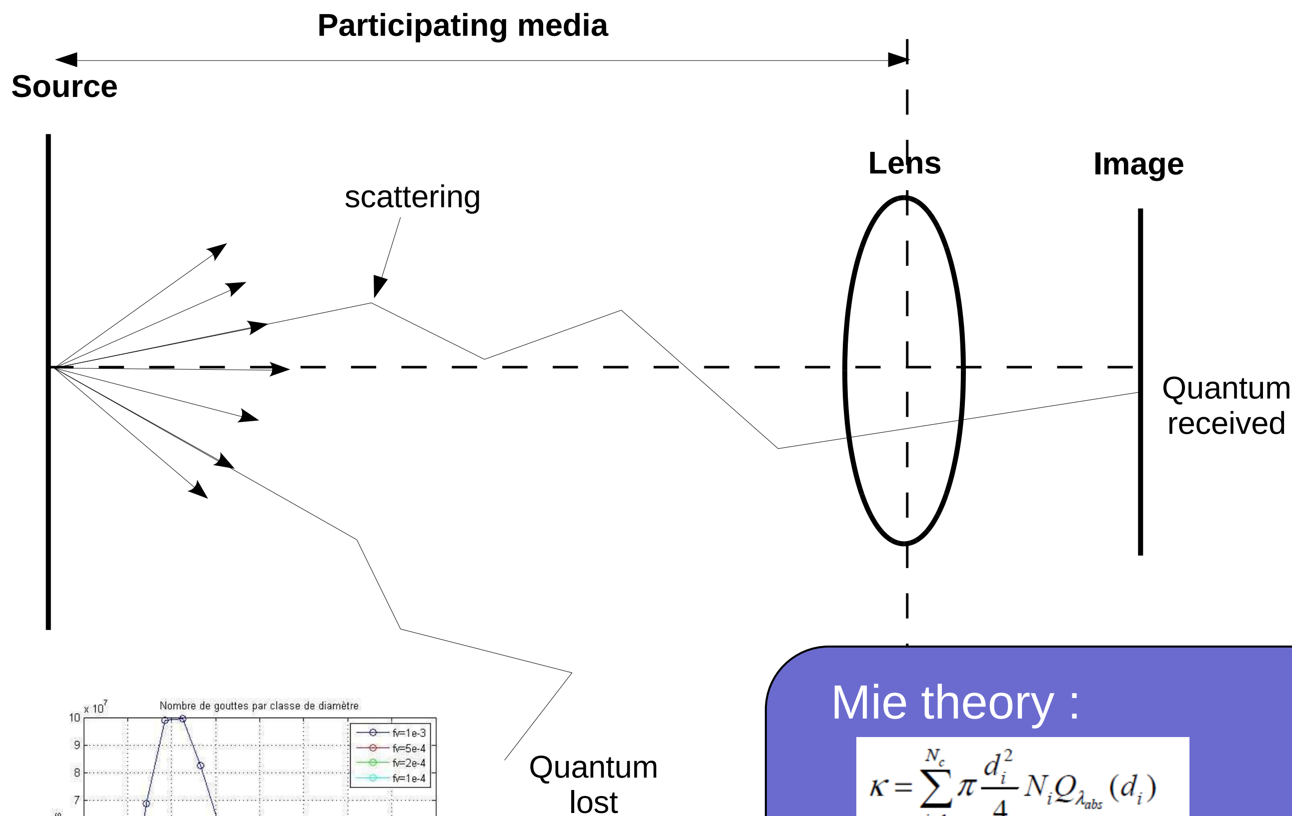

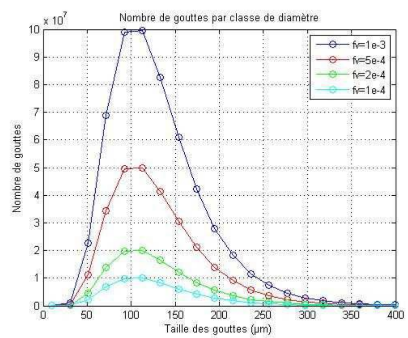

Mie theory :

$$\kappa = \sum_{i=1}^{N_c} \pi \frac{d_i^2}{4} N_i Q_{\lambda_{abs}}(d_i)$$

$$\sigma = \sum_{i=1}^{N_c} \pi \frac{d_i^2}{4} N_i Q_{\lambda_{diff}}(d_i)$$

$$P_\lambda^{Mie}(\Theta) = \frac{1}{\sigma} \sum_{i=1}^{N_c} \pi \frac{d_i^2}{4} Q_{\lambda_{diff}}(d_i) P_\lambda^{Mie}(d_i, \Theta) N_i$$

Main results

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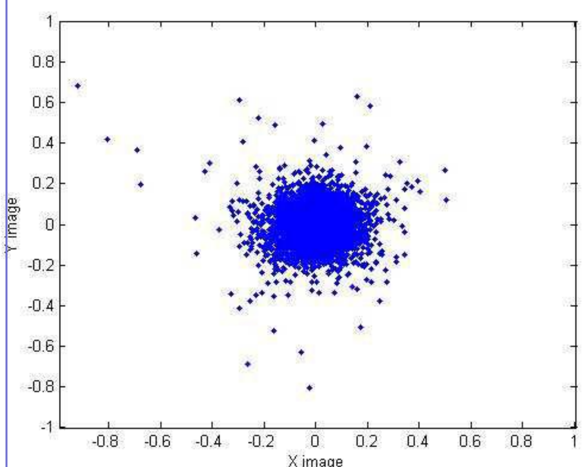
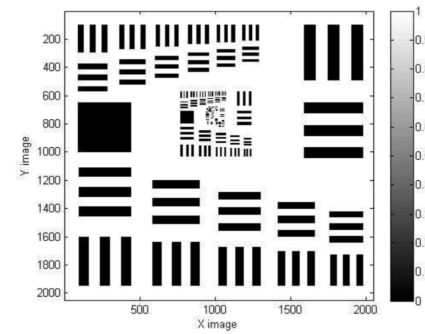
For an isolated point



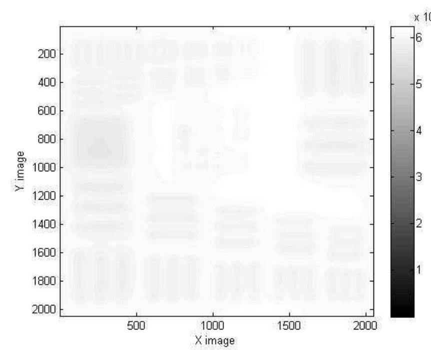
λ = 500 nm
Water volumetric
concentration 1.10-3
Optical depth of 0.1m

For a test pattern

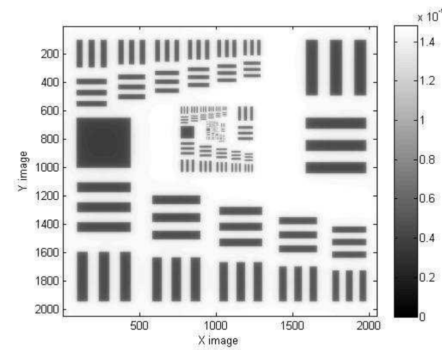
Source



Its images



λ = 500 nm
$f_v = 1.10^{-3}$
d = 0.1m



λ = 500 nm
$f_v = 2.10^{-4}$
d = 0.1m

Conclusion

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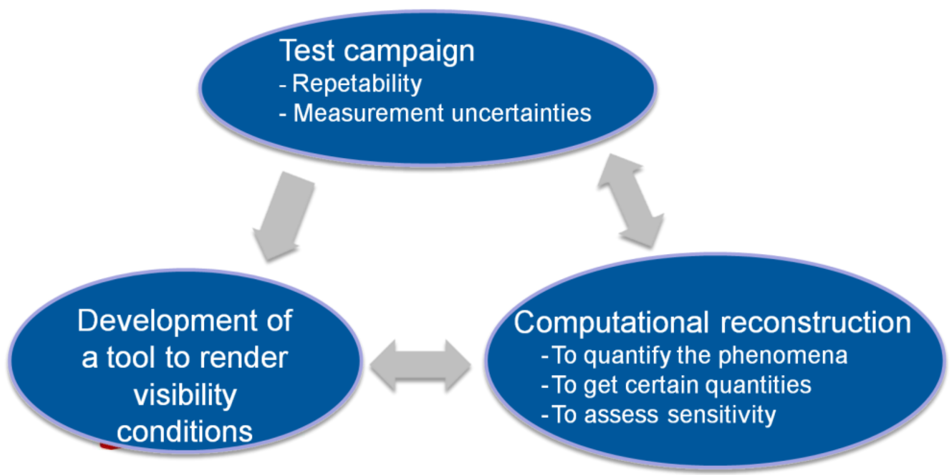
Before mist activation

Thermal and optical stratifications appear coupled

After mist activation

- Gas temperature become homogeneous downstream WM explained by mixing and cooling
- Whereas opacity is not homogeneous: its is even lower close to the floor than at mid-height

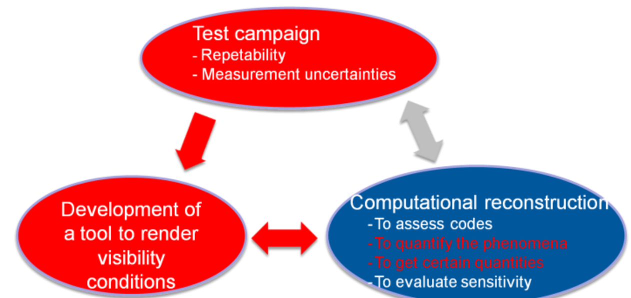


The tool currently developed appears promising

FDS developed by NIST and VTT captured well the trends before and after mist activation

Prospects

- Design an instrumentation enabled to measure opacity in severe conditions (hot and wet gases with water droplets)
- Test other fuel loads, **water spray systems** by varying the number of activated nozzles, its(theri) position to their effect
- Quantify the involved phenomena: How much radiation attenuation represents compared to surface cooling with a WM ?
- Add gas contribution within the visualization tool
- Find a way to assess this tool



Thank you for your attention !