GdR MBS
MATÉRIAUX de CONSTRUCTION BIOSOURCÉS

1er Webinaire Inter-GdR "l'eau face aux biosourcés"

# L'eau dans les matériaux biosourcés : équilibre et transfert

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CentraleSupélec | université PARIS-SACLAY

LGPM
GÉNIE DES PROCÉDÉS ET MATÉRIAUX

Chaire de Biotechnologie
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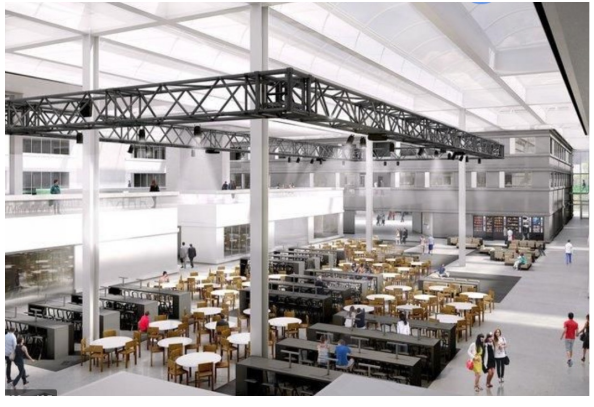
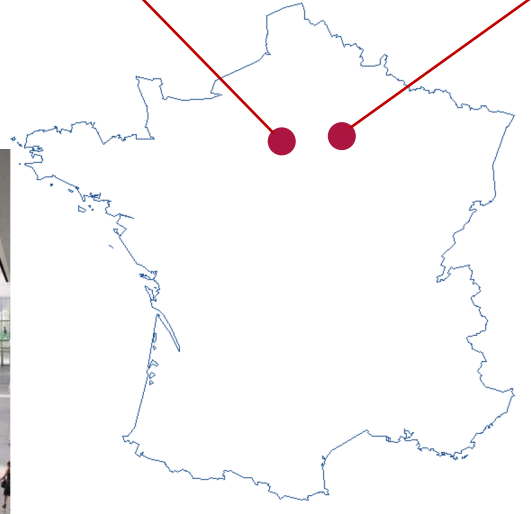
A group 40 at the CEBB,
at the heart of the biorefinery of
Bazancourt-Pomacle (nearby Reims)





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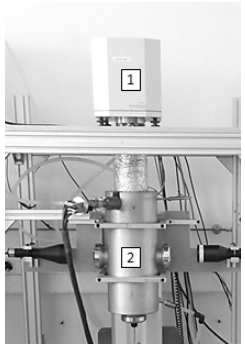
# Votre programme

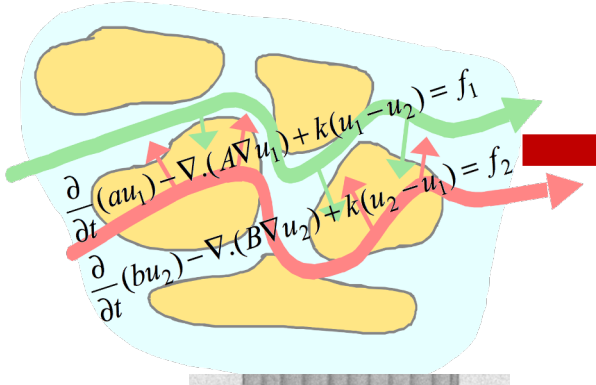
- Équilibre (temps infini)
- Transfert (temps fini)
  - Diffusion (vapeur + eau liée),
  - Migration liquide

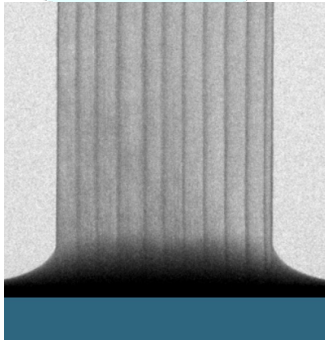
- Effets de l'histoire du chargement
- Effets multiéchelles

Comment caractériser et prédire ?

# L’eau et les matériaux biosourcés



Dimensional stability
Mechanical properties

Aging
Durability
Biodegradation

Energy in building

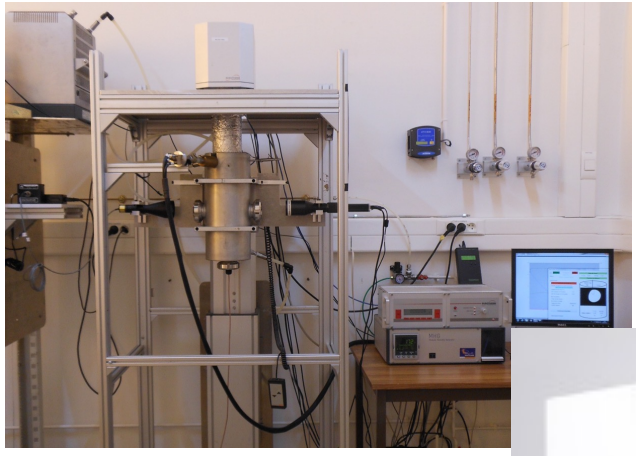
Drying
Storage

# Temps longs : isothermes de sorption

- Equilibre entre teneur en eau liée et humidité relative de l'air environnant,
- Questions au-delà de l'apparente simplicité :
  - Durée des essais ?
  - Taille échantillons ?
  - Stabilité des conditions ambiantes ?

# Détermination expérimentale

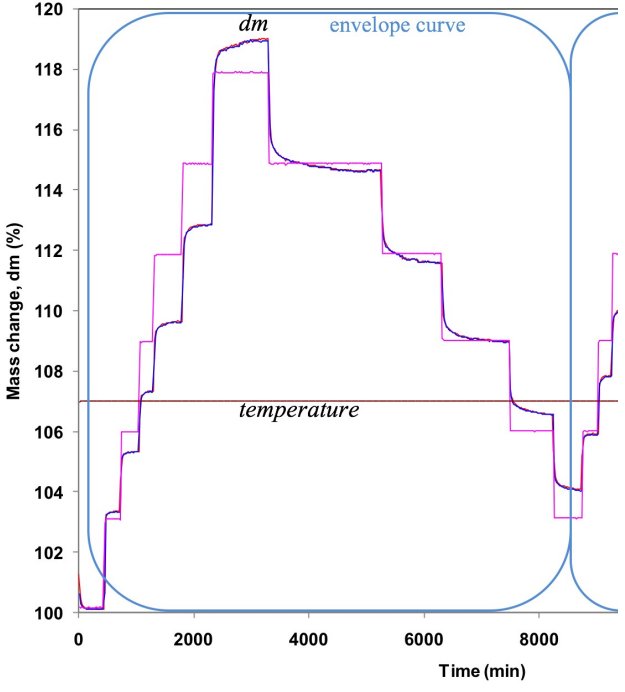
**Rubotherm (suspension magnétique)**

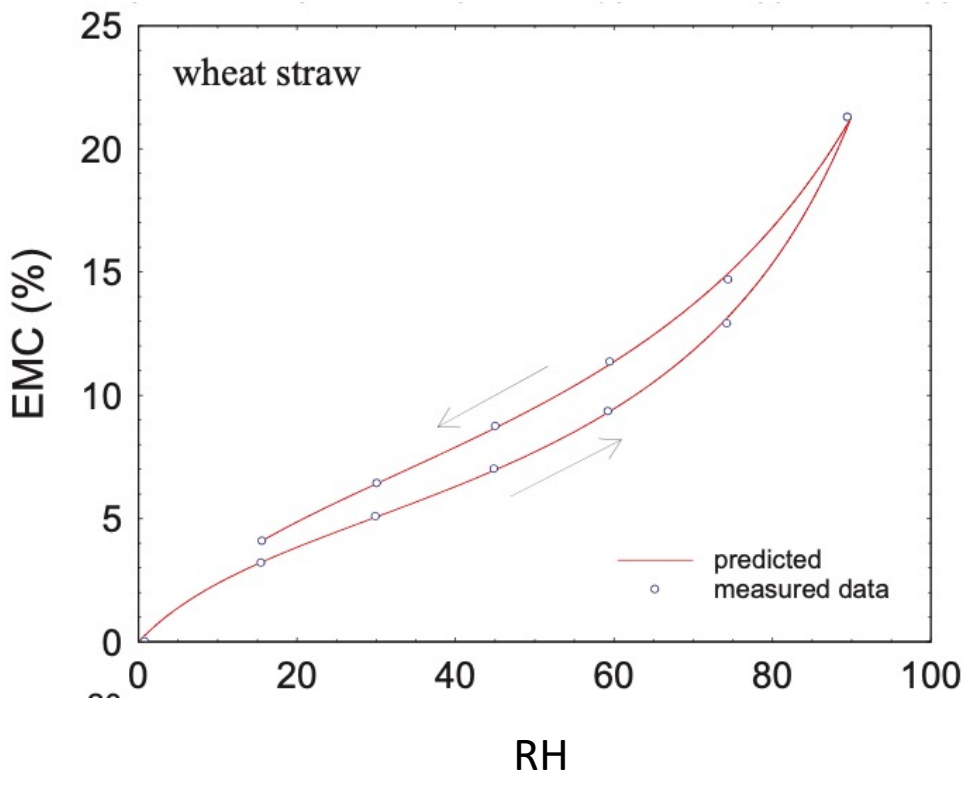



**Micro-DVS**

**ProUmid GmbH**

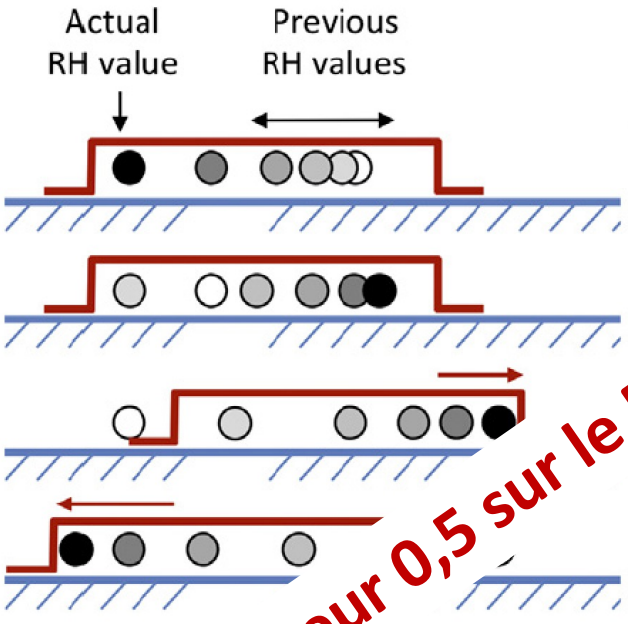
# Temps longs : isothermes de sorption

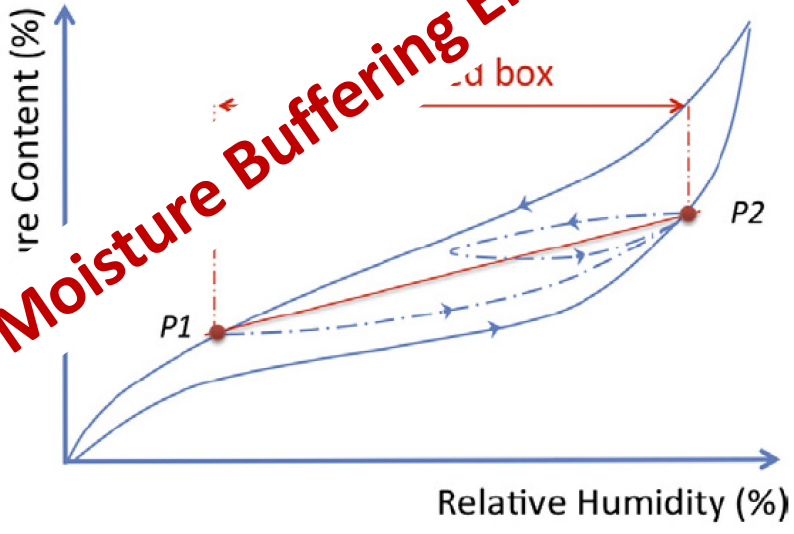



Almeida, Rémond, Perré, J. Building Engineering 2018

# Variations HR en conditions réelles

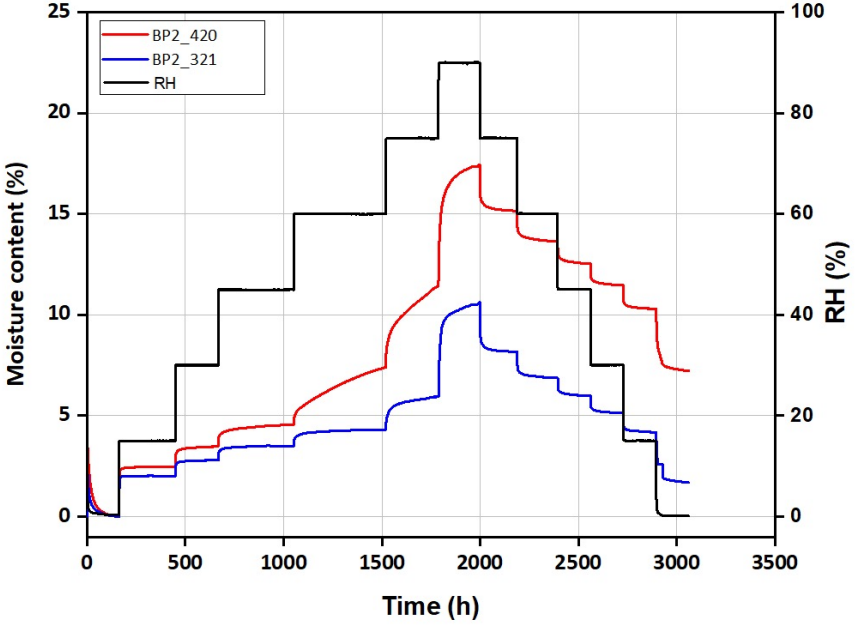


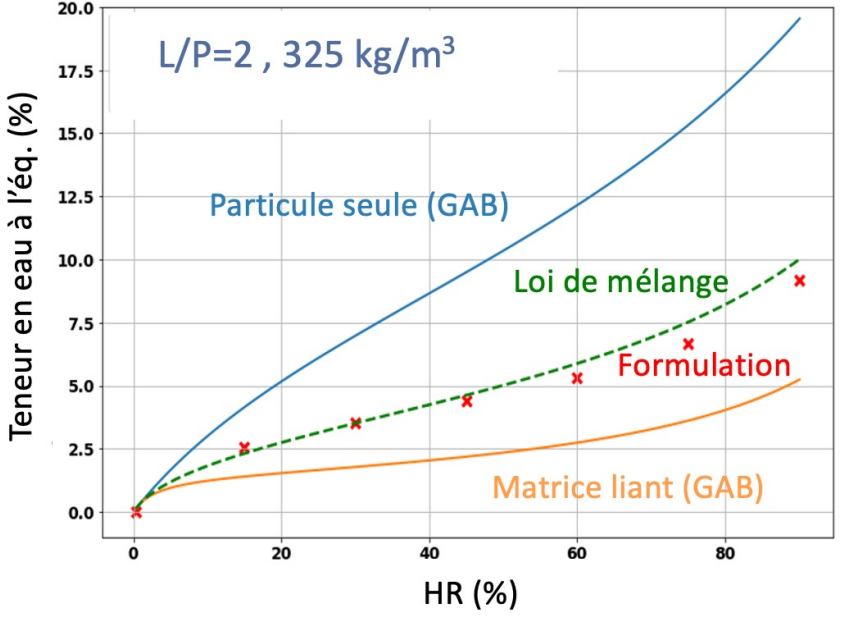

**Facteur 0,5 sur le Moisture Buffering Effect**

Rémond, Almeida, Perré, Construction and Building Materials, 2018

# Physio-sorption vs chimio-sorption
# bétons chanvre-chaux




Désorption = correction de l'irréversible




Mazian, Almeida, Frantz, Perré, in preparation

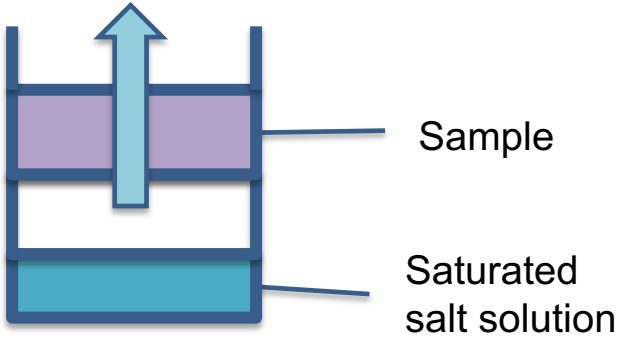
# Etat hors d'équilibre : migration d'humidité

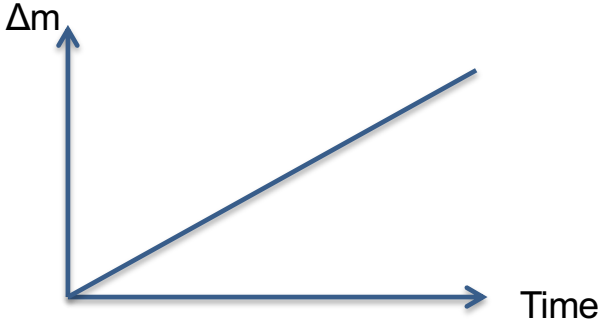
- Diffusion de vapeur d'eau
  - Force motrice = gradient fraction massique
- Diffusion d'eau liée
  - Force motrice = ???
- Migration capillaire dans le réseau de pores
  - Force motrice = gradient de Pc
- Eventuellement, mouvement convectif (loi de Darcy)
  - Force motrice = gradient de pression totale

# Diffusivité

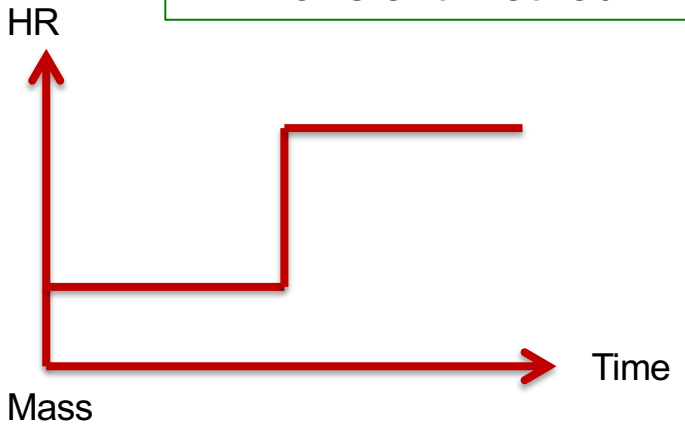
# Mass diffusivity measurement

Cup method

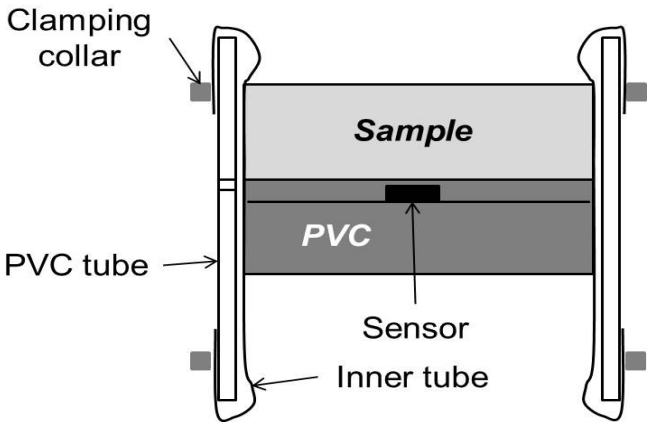



Transient method



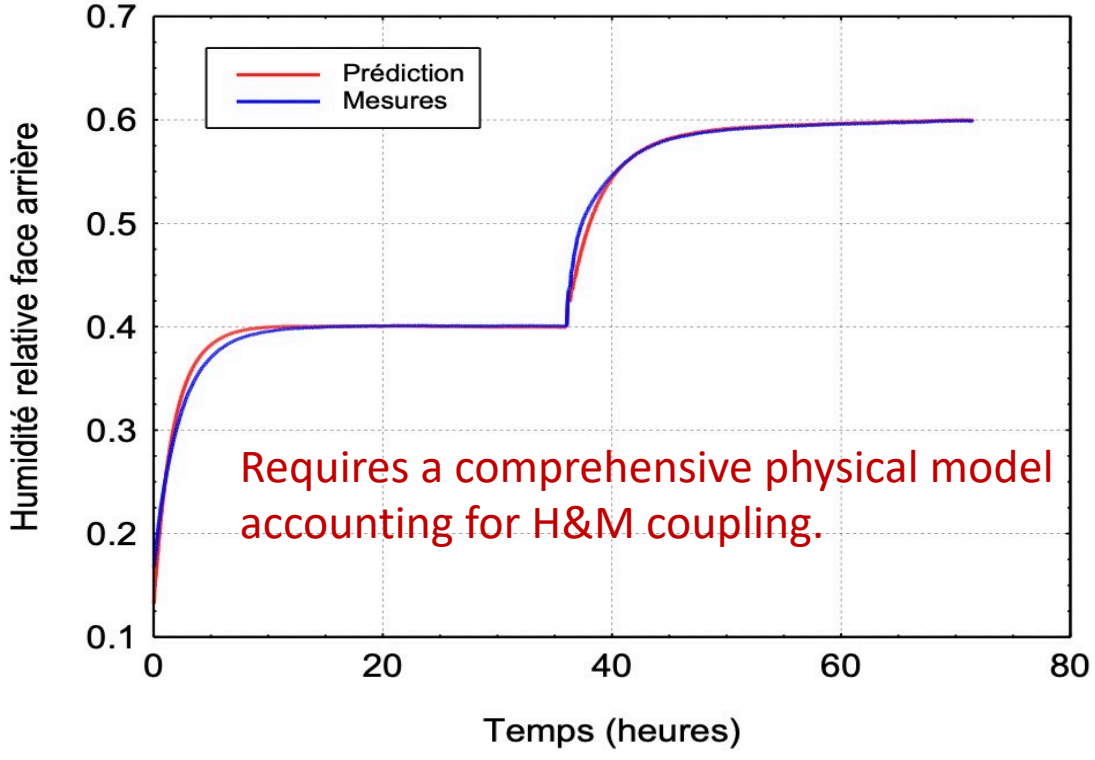
# The back-face method





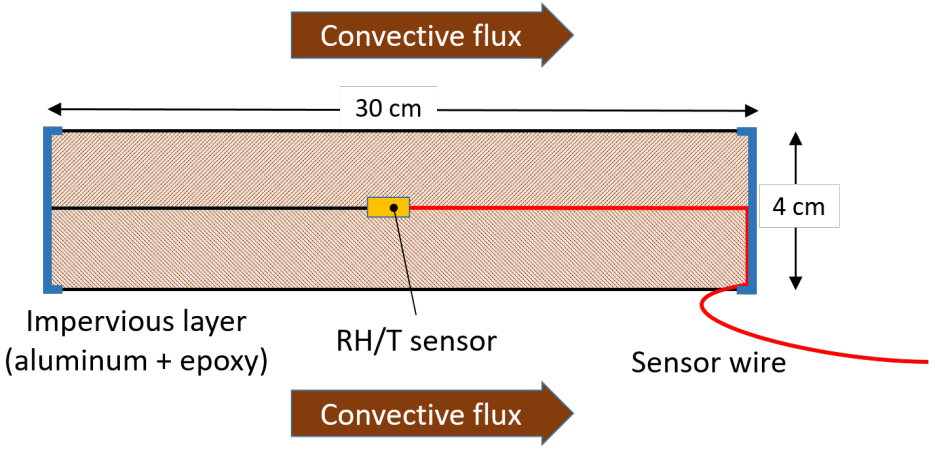

Perré, Pierre, Casalihno, Ayouz, Drying Technology, 2015

# Inverse analysis of the RH on the backside




Perré P., Pierre F., Casalinho J., Ayouz M., Drying Technology, 2015

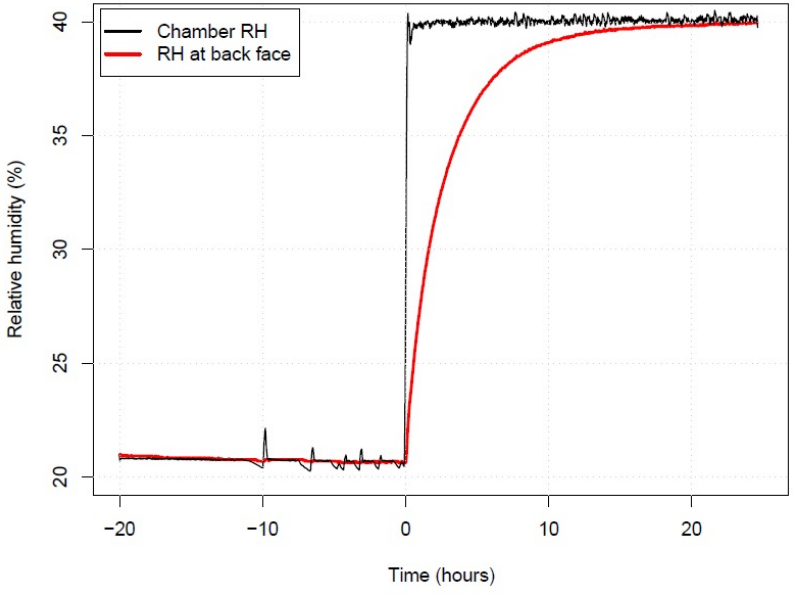
# Couplage chaleur/masse

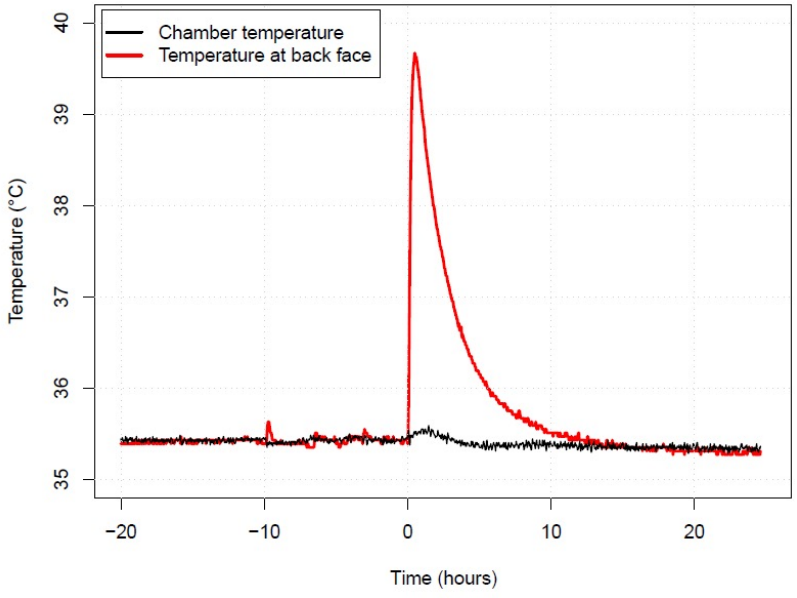



Sudden change to 40% RH after equilibrium at 20% RH

Perré, P. , Challansonnex, A., Colin, J. (2019), Int. J. Heat Mass Transfer 133, 968-975.

# Exp. results



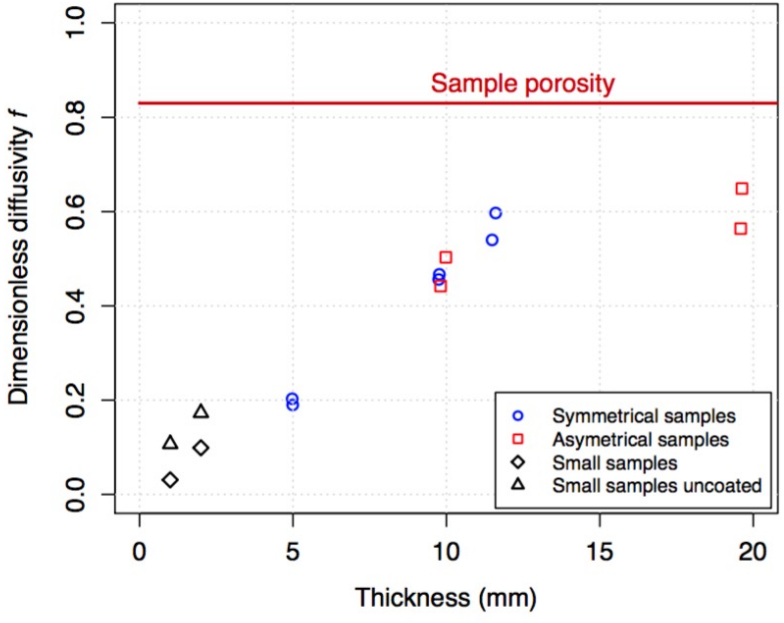




Impressive temperature peak in value (4°C) and duration (10 hours)

Perré, Challansonnex, Colin (2019) Int. J. Heat Mass Transfer 133, 968-975.

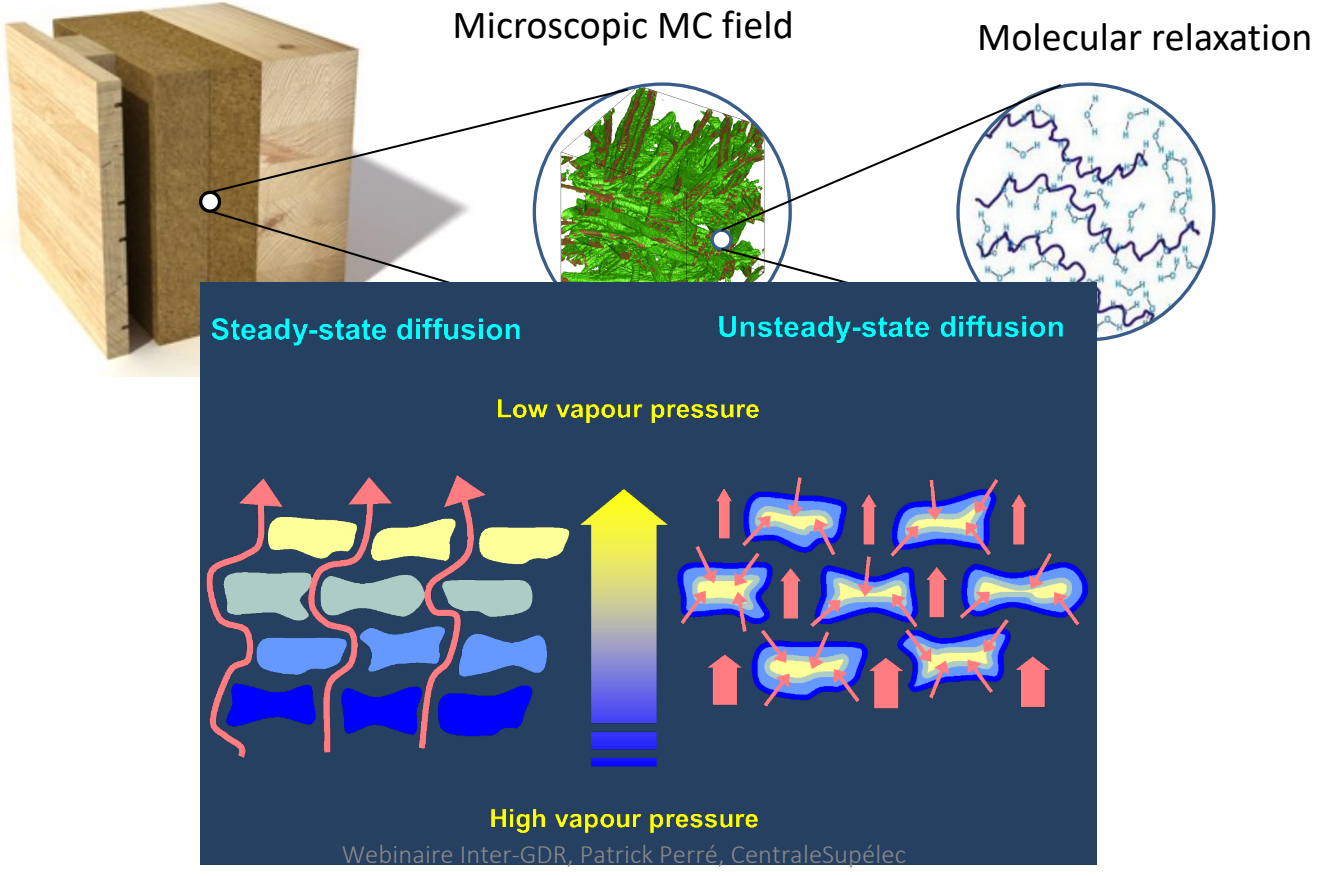
# Effects double échelle

# D = f (thickness)



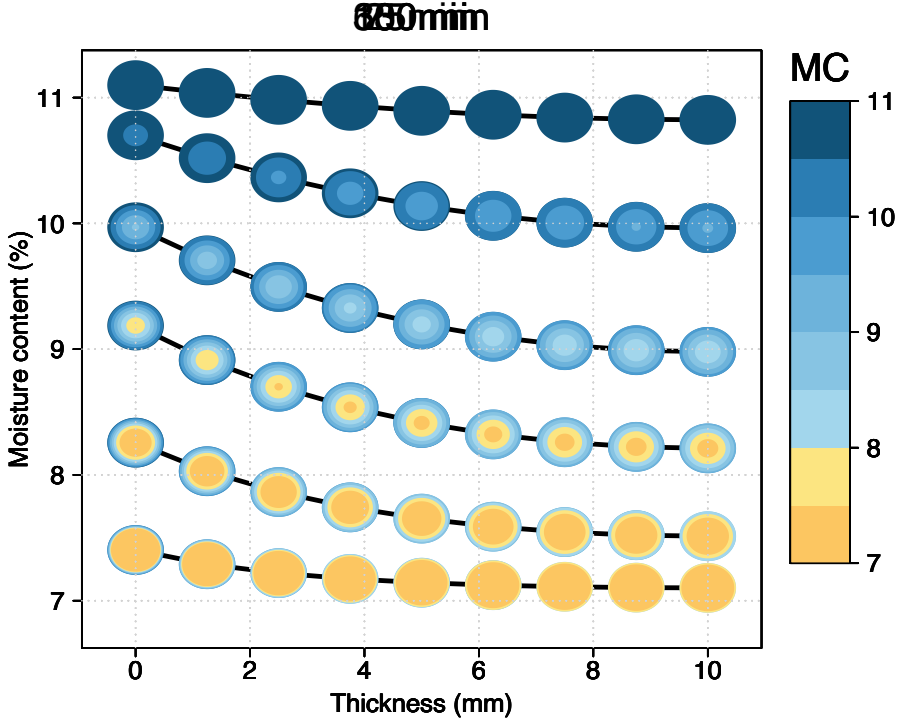

The diffusion coefficient is no longer an intrinsic parameter

# Memory effects in low density fiberboard



# Dual scale simulation

Slow diffusion in fibres slows down the macroscopic evolution




P. Perré (2019), Int. J. Heat Mass Transfer, 140: 717–730

# Macroscopic formulation : memory function

The modified heat & mass transfer model

*Moisture conservation*

$$\frac{\partial}{\partial t}\left(aX_{eq}+\int_0^t k(t-\tau)X_{eq}d\tau\right)=\nabla\cdot(\boldsymbol{D}_b\nabla X_{eq}) \qquad (15)$$

*Energy conservation*

$$\frac{\partial}{\partial t}\left(\rho_b\overline{h}_b+\varepsilon_s\rho_s h_s\right)=\nabla\cdot(\lambda_{eff}\nabla T+h_b\rho_s\boldsymbol{D}_b\nabla X_{eq}) \qquad (16)$$

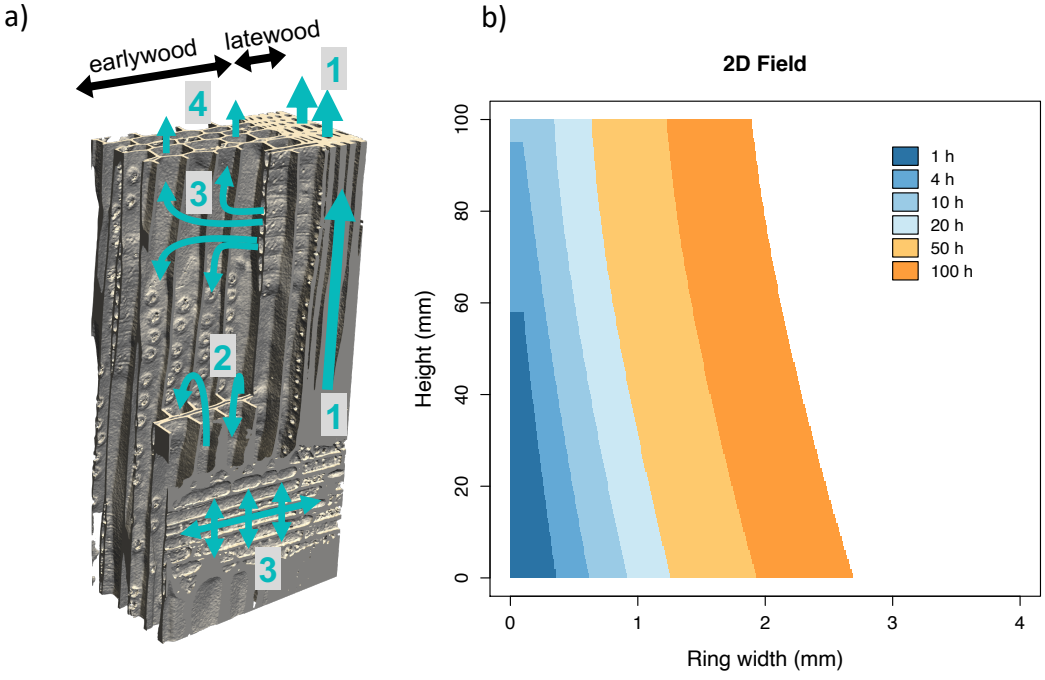
*Non-local equilibrium*

$$X(t)=X_{eq}(t)-\sum_i \phi_i(t) \qquad (17)$$

**One internal variable per exponential function**

P. Perré, Int. J. Heat Mass Transfer, 140: 717–730, 2019

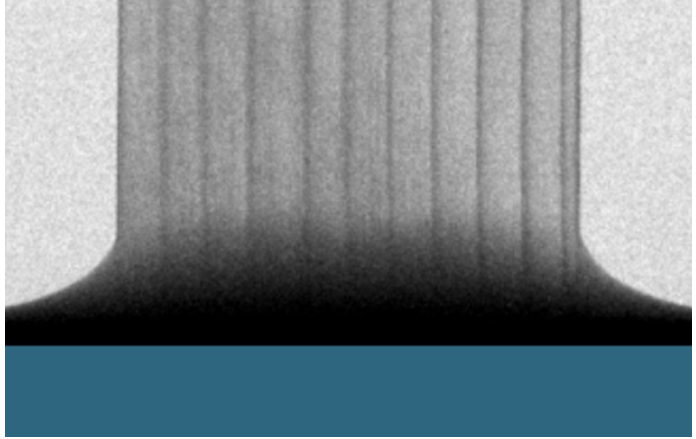
# Migration liquide




Perré et al. *Scientific Reports,* 12(1), 1-14., 2022.
Martin, *et al. Holzforschung*, 2023

# Conclusions

- Des équilibres aux transferts multiphysiques et multiéchelles → complexité croissance
- L'histoire du chargement hydrique et effet multiéchelle sont déterminants
- Proposer des formulations simples capables de prédire reste un défi de taille…



# *Thank you for your attention !*