On the Drying Dynamics in Biofilters

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On the Drying Dynamics in Biofilters → OUTLINE

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- Motivation / Introduction on Biofilters
- Governing equations of Flow & Drying
- 1-D model (Mathematica)
- 2-D and 3-D models (COMSOL)
- Summary of Results & Outlook

Motivation / Introduction

Biofilter (BF):

High-Performance Container BF:

application areas:

paint spraying shops, breweries, chemical industries, landfills, foundries, coffee & cocoa roasting, plastics processing, food processing, mushroom cultivation, fish-smoking, residual waste treatment, slaughterhouse, rubber - and plastic industries …

Motivation / Introduction

The art of operating BFs:

+ ….
+ ….
+ Keep the right amount of water:

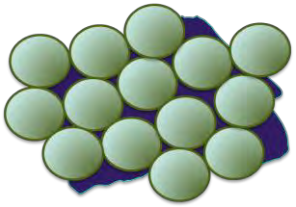
too much water → agglomeration / clogging
too little water → complete drying

- **How does the drying in BFs occur?**
- **Are heterogeneities in the moisture cured with time or do they increase?**
- **Drying dynamics?**

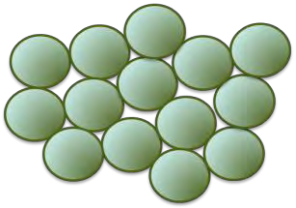
Governing Equations / 1-D Model

$y=y(t)$: average volume fraction of liquid water within the pores

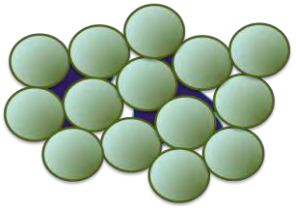
$y = 1$ → completely filled (clogging)



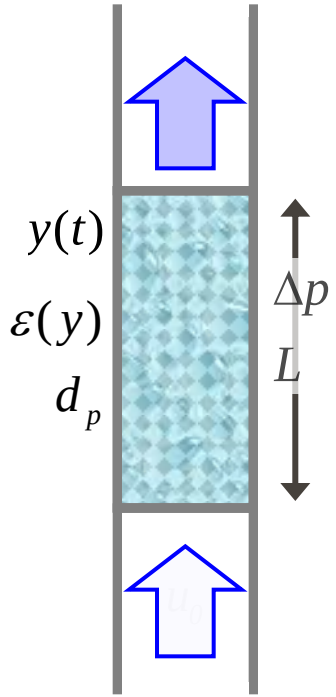
$y = 0$ → completely dried out



$0<y<1$ →



1-D model:



The effective porosity depends on the moisture content, e.g.:

$$\varepsilon = \varepsilon(y) = \varepsilon_0(1-y)$$

Governing Equations / 1-D Model

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$$Sh = 2 + 1.8\, Sc^{1/3}\, \mathrm{Re}^{1/2}$$

$$\dot{y} = \ldots Sh(u_0)\left(c^g_{H_2O,equ} - c^g_{H_2O}\right)$$

$$\frac{dp}{dz} = 150\frac{(1-\varepsilon)^2}{\varepsilon^3}\frac{\eta_g}{d_p^2}u_0 + 1.74\frac{1-\varepsilon}{\varepsilon^3}\frac{\rho_g}{d_p}u_0^2$$

$$\varepsilon = \varepsilon(y) = \varepsilon_0(1-y)$$

$$\dot{y} = -\alpha\left(2 + 1.8\beta\delta\left(\frac{1}{1-\varepsilon_0(1-y)} - 1\right)\right)$$

… we have a closed system of coupled equations.

$$\alpha = 6\frac{1-\varepsilon_0}{\varepsilon_0}\frac{D^g_{H_2O}}{d_p^2}\frac{\Delta c^g_{H_2O}}{\rho_l} \qquad \beta = \left(D^g_{H_2O}\right)^{-1/3} d_p^{1/2}\, \nu_g^{-1/6} \qquad \delta = d_p\left(\frac{\Delta p}{150 L\, \mu_g}\right)^{1/2}$$

Homogeneous (1-D) Model for Drying in Biofilters

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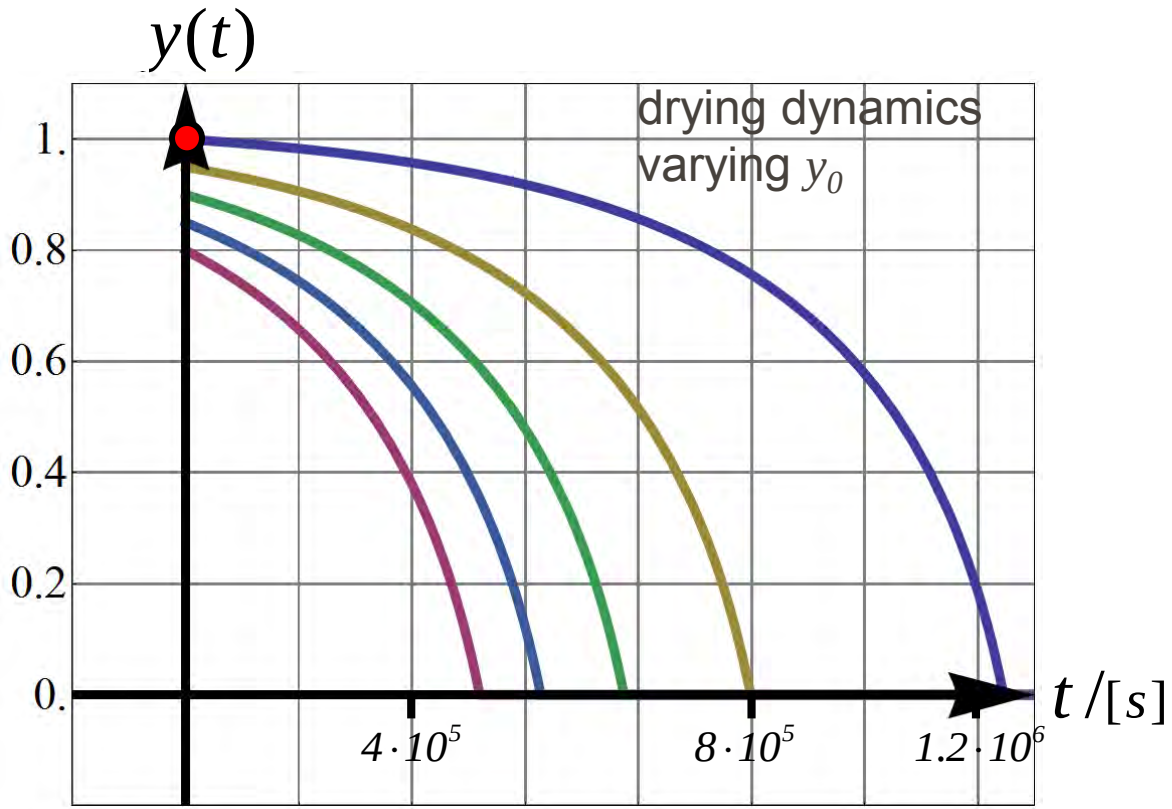
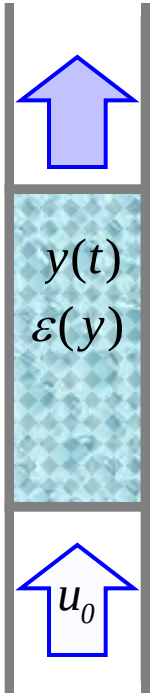
$$\dot{y} = -\alpha\left(2 + 1.8\beta\,\delta\left(\frac{1}{1-\varepsilon_0(1-y)} - 1\right)\right)$$

- DEQ governs the drying dynamics
- no moistening → continuous decrease



Homogeneous (1-D) Model for Drying in Biofilters

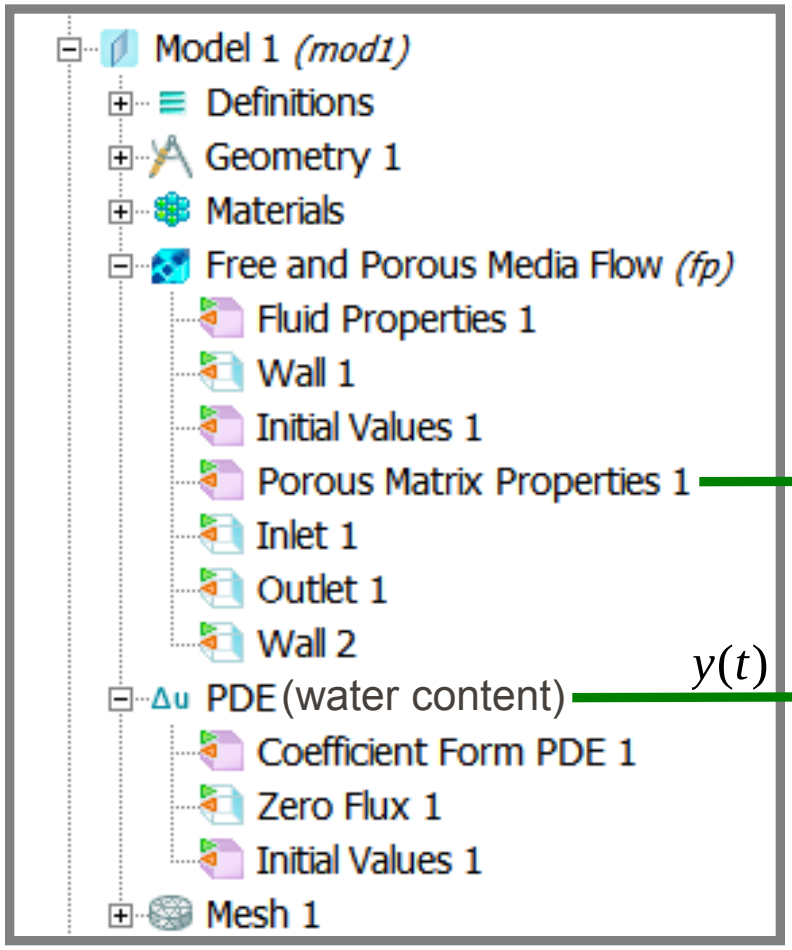
1-D model → drying times do sensitively depend on the initial conditions

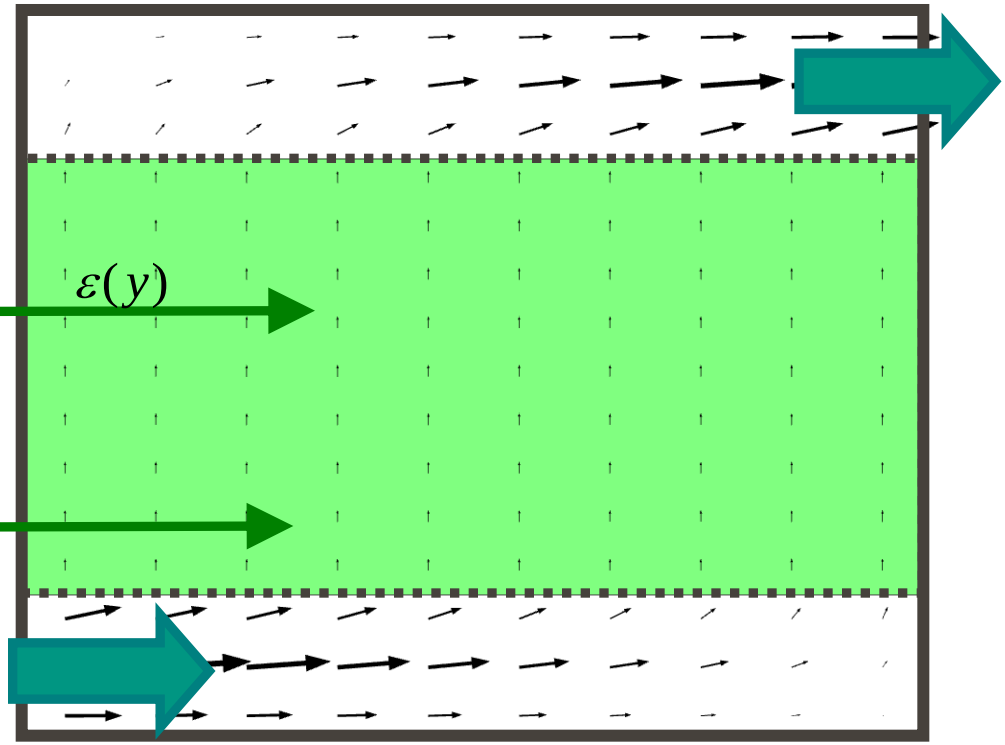


What are the consequences for
2-D, 3-D models and the real world?

2-D Model for Drying in Biofilters

Implementation in COMSOL Multiphysics





Homogeneous 1-D Model (Mathematica)
Homogeneous 2-D Model (COMSOL)

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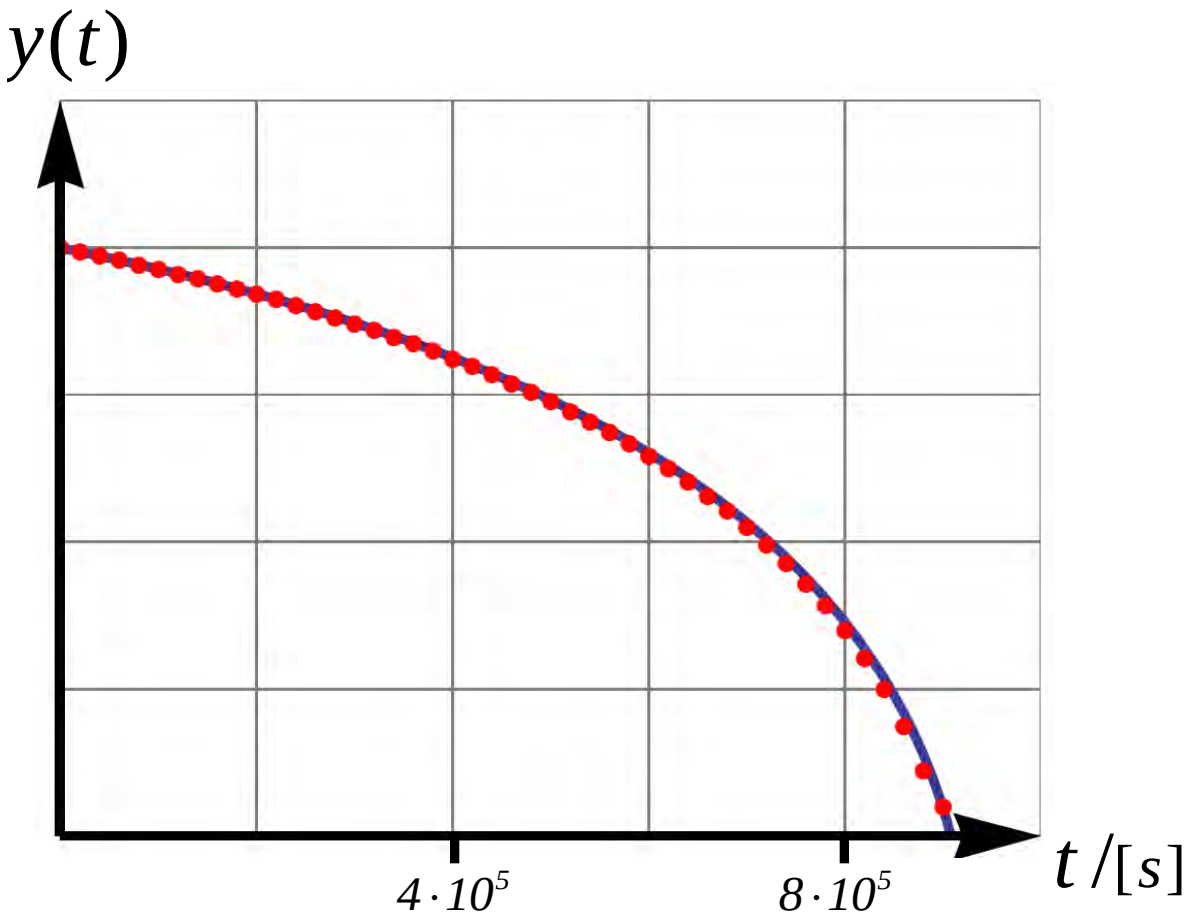
Model Validation

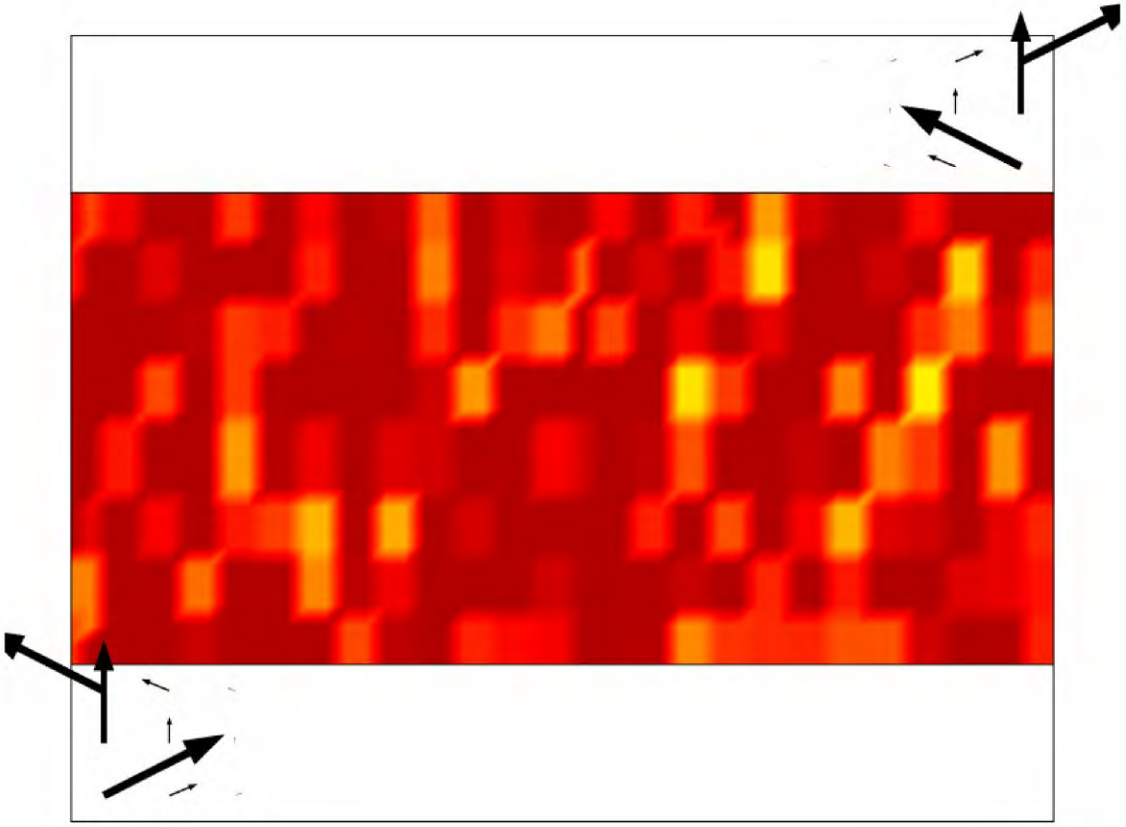


Elements: 2000
Fluid: P2-P1
PDE: Lagrange quadratic

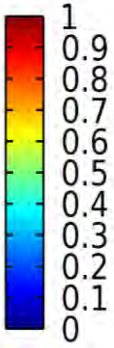
DOF: 24 400

2-D Model for Drying in Biofilters

Heterogeneous initial water distribution



legend water content:

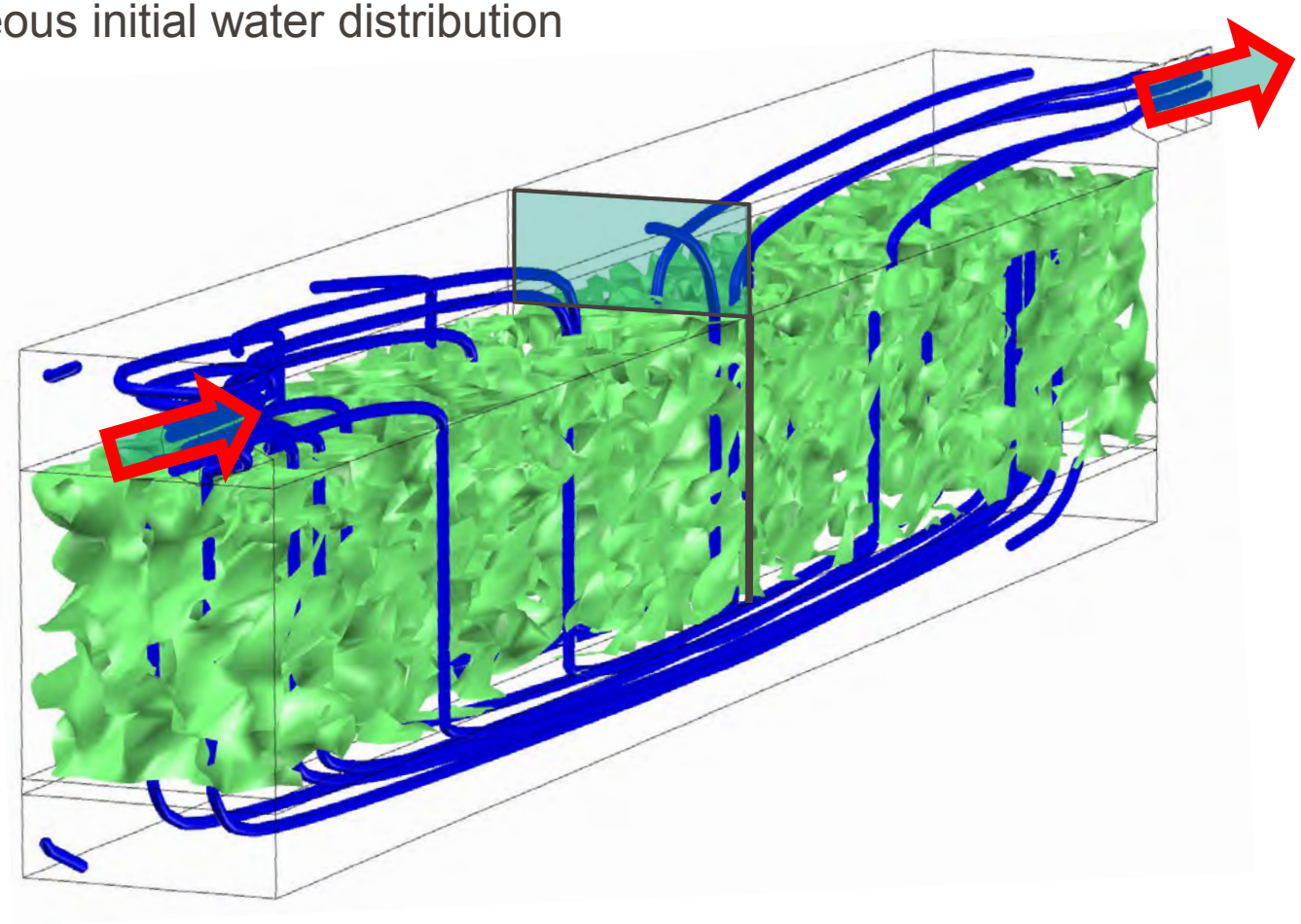


Channeling:
the gas flow is focused to dry regions, by-passing the still active parts of the filter medium

Relative small initial inhomogeneities can lead to a breakdown, due completely dried passages.

3-D Model for Drying in Biofilters

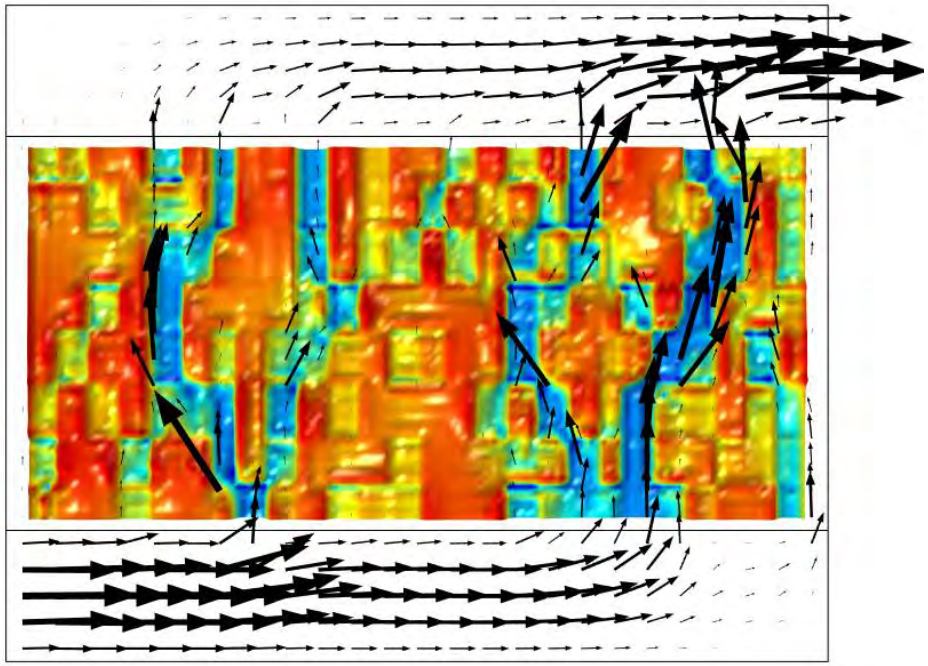
Heterogeneous initial water distribution



Modeling Drying in Biofilters → RESULTS

1-D model → drying times do sensitively depend on the initial conditions

2-D / 3-D model →



Channeling: the gas flow is focused to dry regions, by-passing the still active parts of the filter medium

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On the Drying Dynamics in Biofilters → OUTLOOK

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Experiments:

Modeling:

- 3-D model: investigation of inflow effects on drying
- incorporation of thermal effects (external & internal)
- incorporation of biological aspects
- …

- identifying optimization strategies

Acknowledgements to:

BmBF – ‘Forschung an Fachhochschulen’

You for your attention