Quantification of mesoscale structure

monitored with Optical Coherence Tomography (OCT) helps to understand biofilm processes

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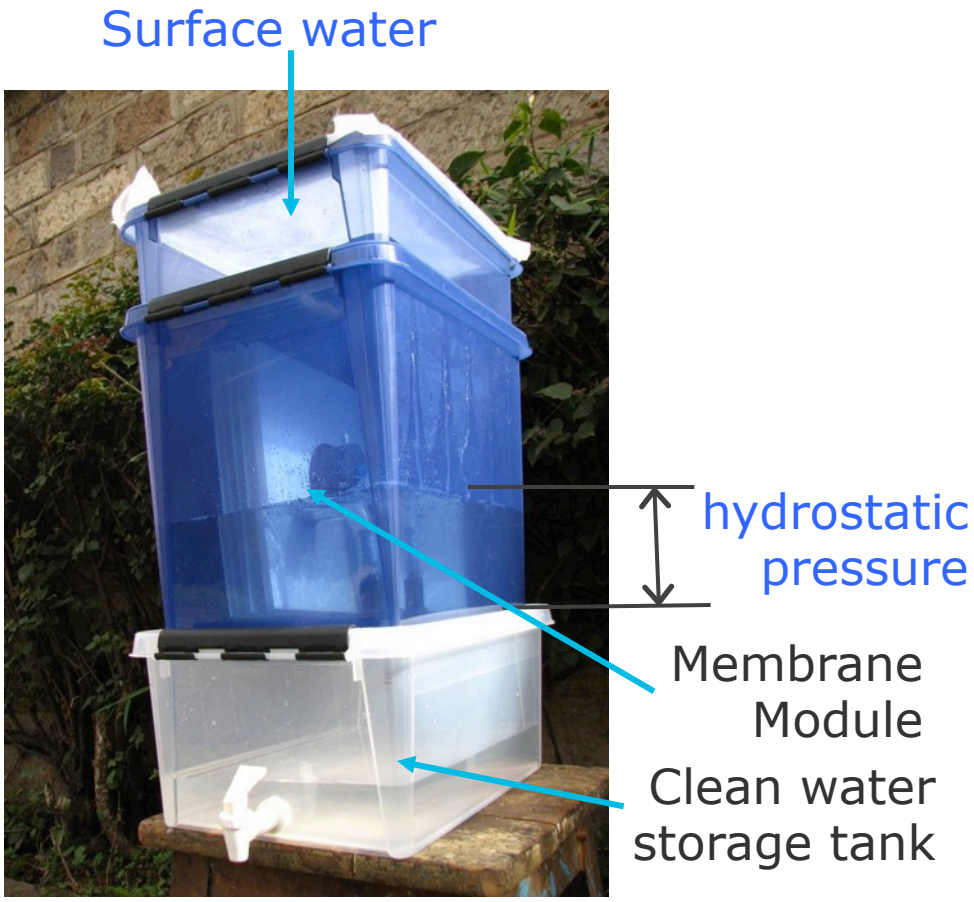
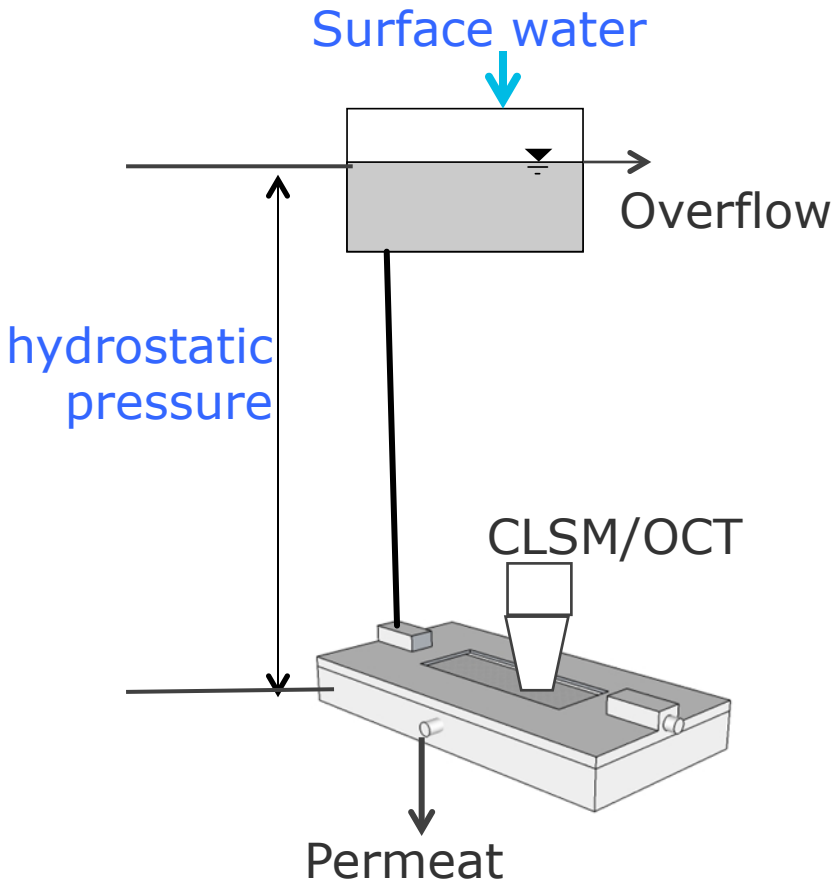
Biofilm conference, Shanghai 2011

Eawag: Swiss Federal Institute of Aquatic Science and Technology

Biofilm structure in Gravity-Driven Membrane (GDM) filtration

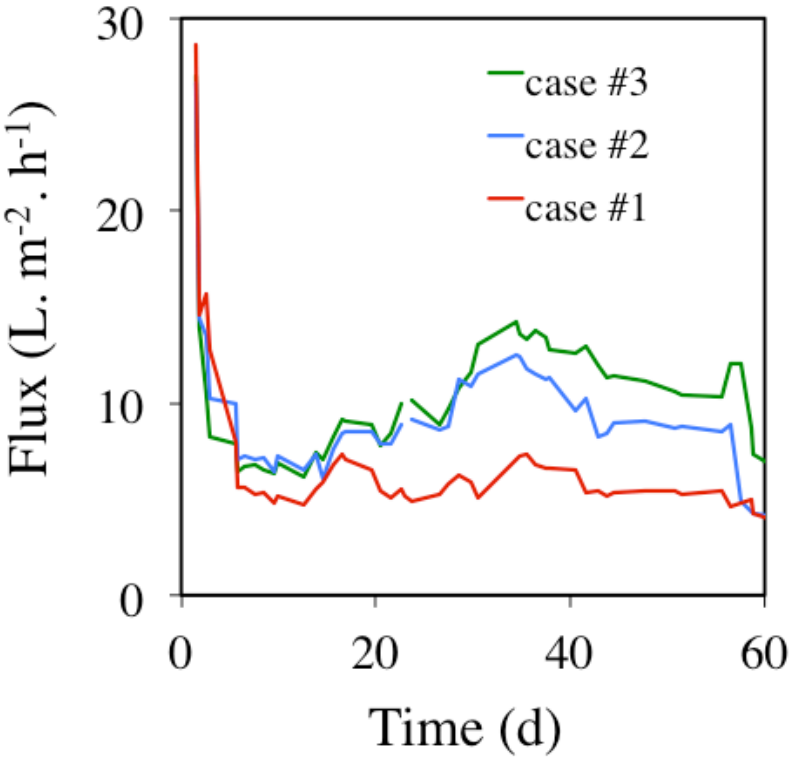


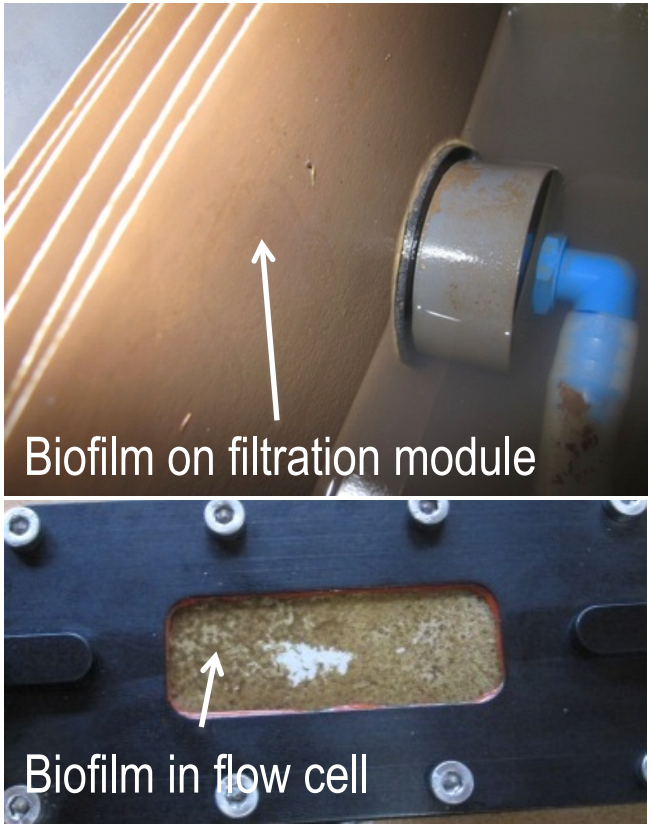


Prototype of GDM system being tested in the field (Kenya).

Laboratory-scale GDM system with flow cell suitable for CLSM and OCT

Biofilm structure in Gravity-Driven Membrane (GDM) filtration





Macro-scale:
flux stabilizes but level of flux stabilization is changing

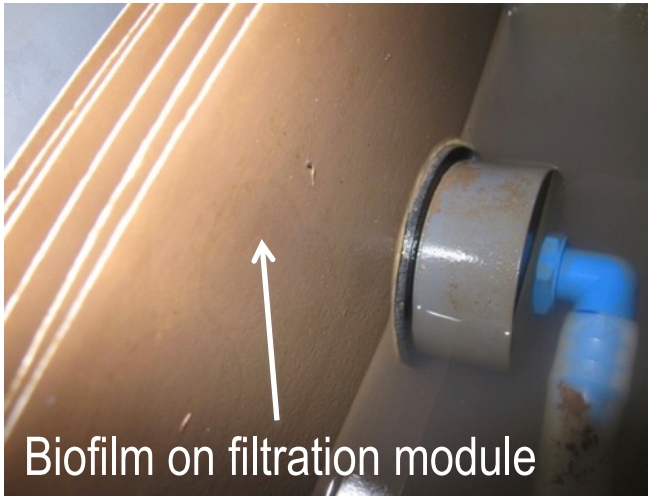
Lab-scale:
Different biofilm structures are observed

Biofilm structure in Gravity-Driven Membrane (GDM) filtration

Objectives:

Linking filtration performances with the formation of different biofilm structures

Demonstrating that meso-scale monitoring and quantification of biofilm structure provide relevant information

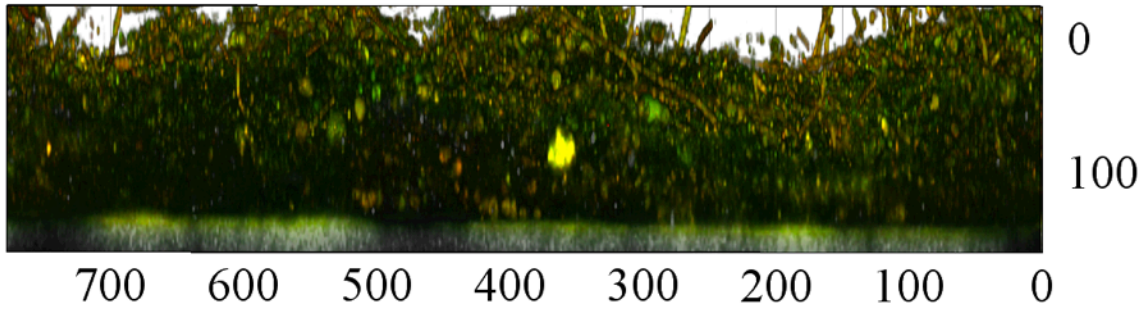


Limited information is provided by micro-scale observation (CLSM)

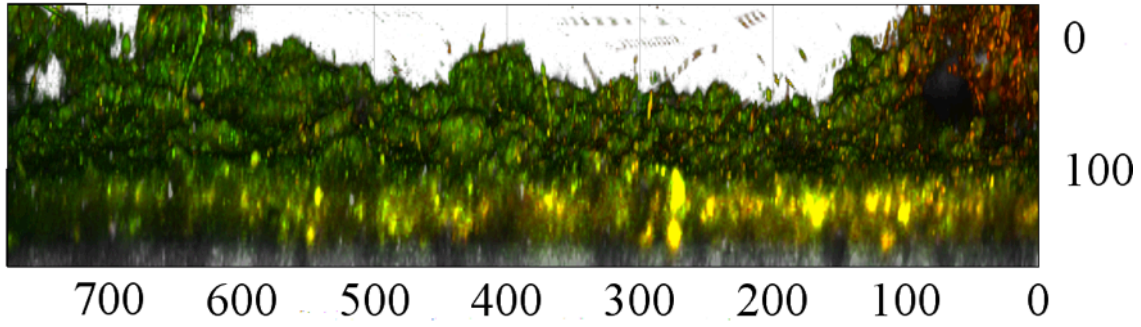
Stable permeate flux (macro-scale)

CLSM observations (micro-scale)

Case 1:
Flux = 5-10 L/m^{2}h



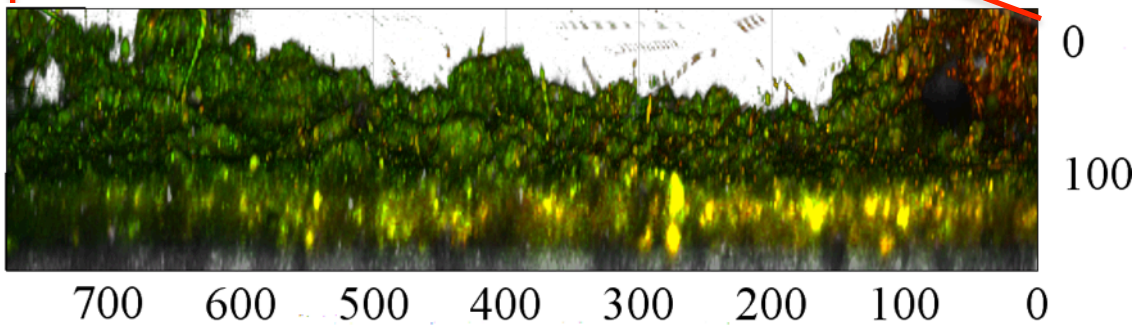
Case 2:
Flux = 3-6 L/m^{2}h



Staining: SybrGold® for nucleic acids (in green) and reflection for particulate matter (in grey)

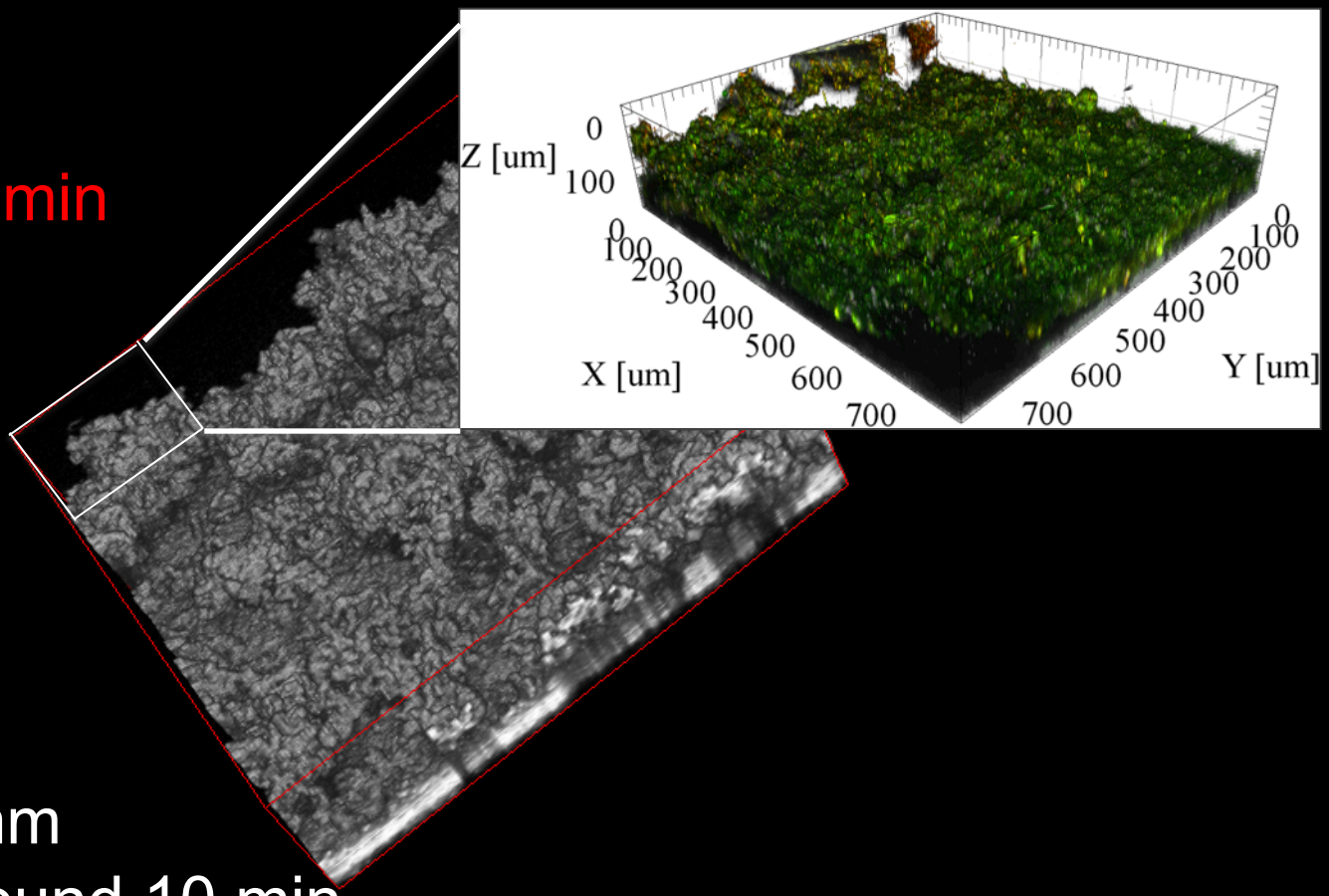
Optical Coherence Tomography (OCT) to monitor large biofilm structure?

Untreated OCT image (1 x 5 mm) of a biofilm developed on UF membrane surface during GDM filtration



Optical Coherence Tomography (OCT) to monitor large biofilm structure?

OCT images:
4 x 4 x 1 mm
Scanning time : 1 min



CLSM:
750 x 750 x 150 mm
Scanning time: around 10 min

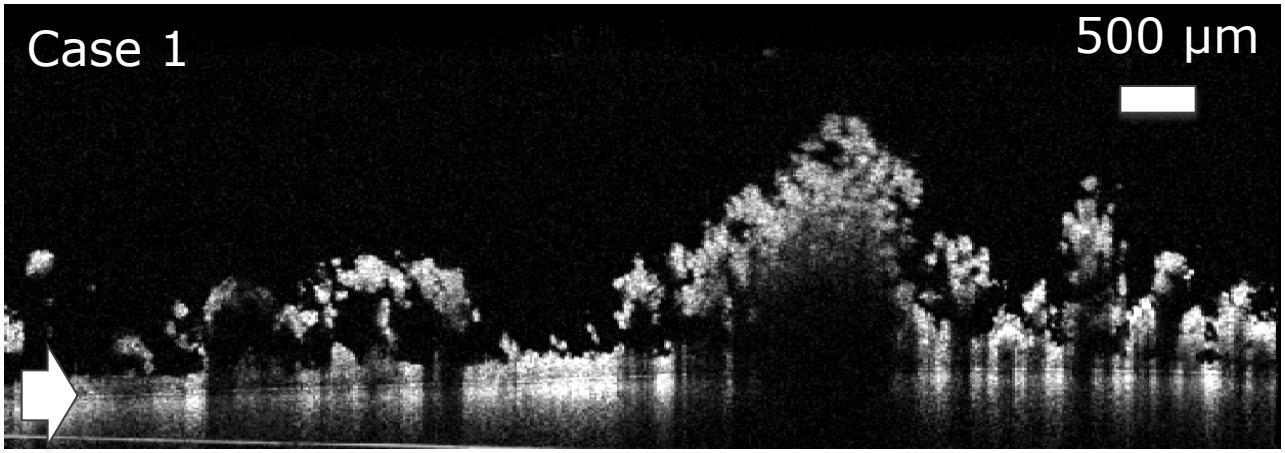
Meso-scale biofilm structure influences filtration performance

Permeate flux (macro-scale)

OCT observations (meso-scale)

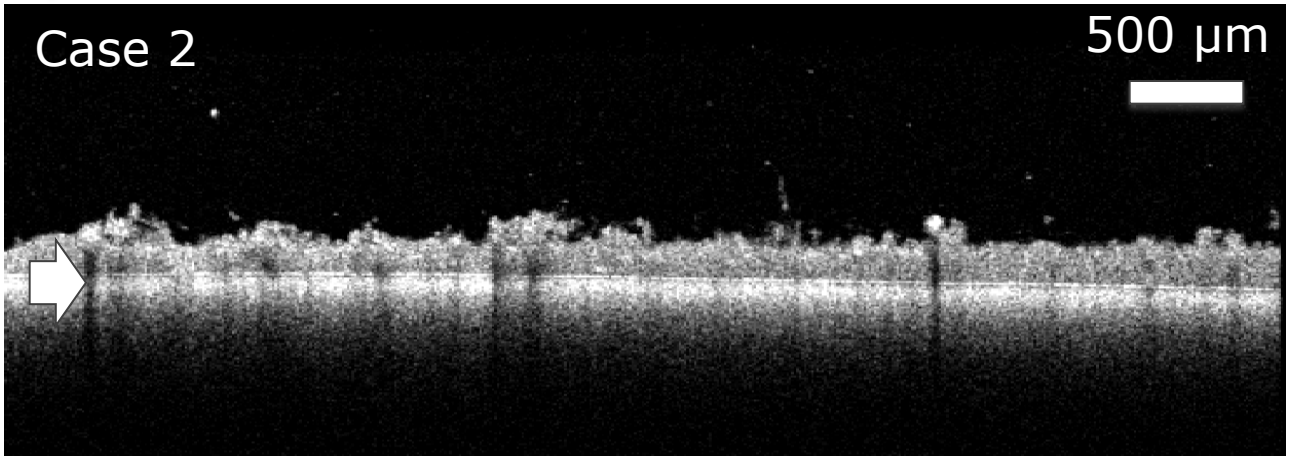
Case 1:

Flux = 5-10 L/m^{2}h



Case 2:

Flux = 3-6 L/m^{2}h



Meso-scale biofilm structure influences filtration performance

Permeate flux (macro-scale)

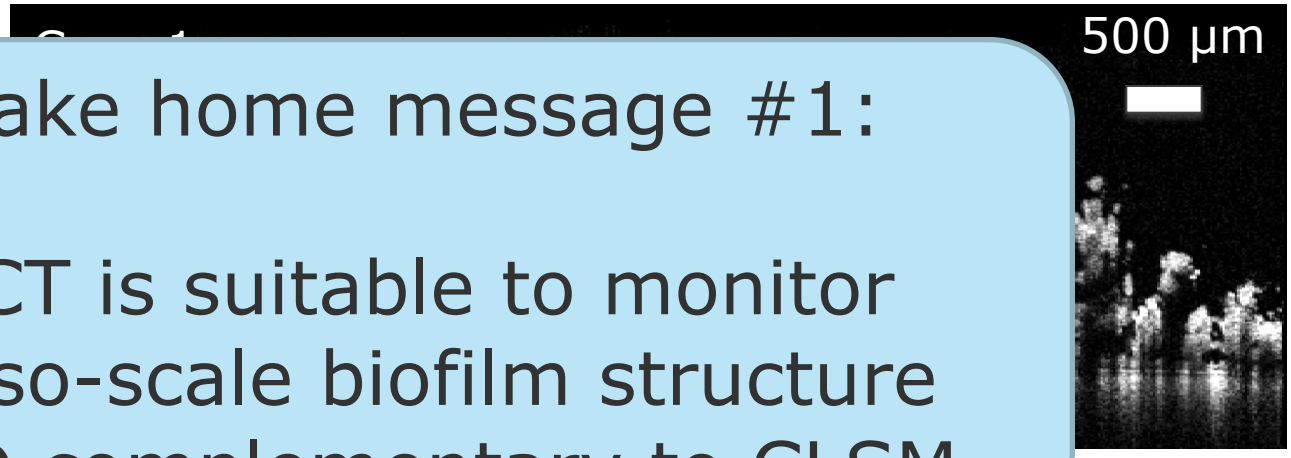
OCT observations (meso-scale)

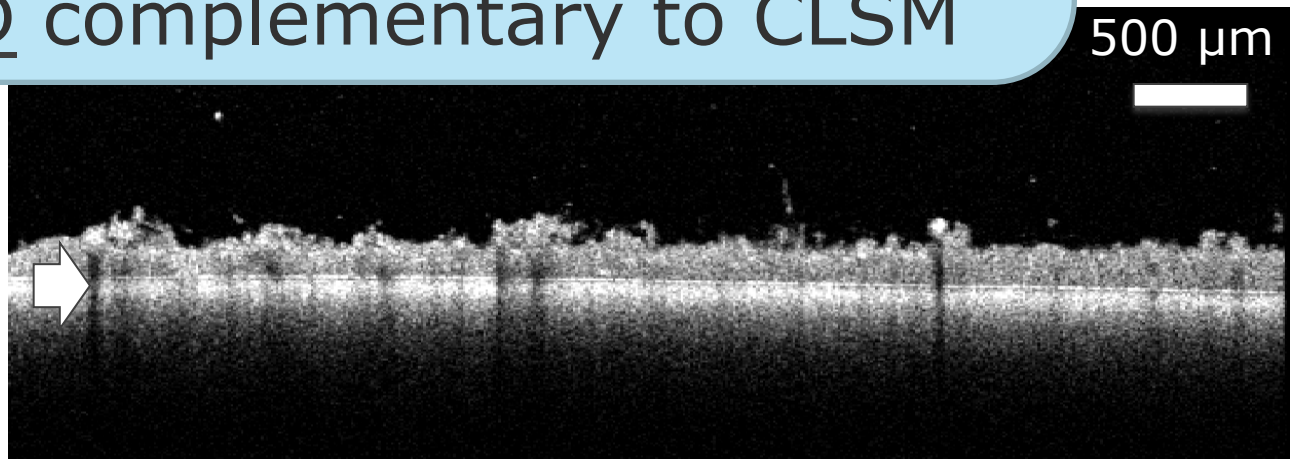
Case 1:

Flux = 5-10

Case 2:

Flux = 3-6 L/m^{2}h



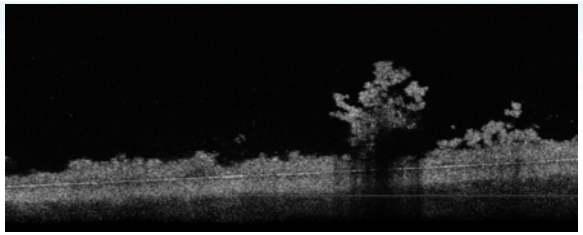


Take home message #1:

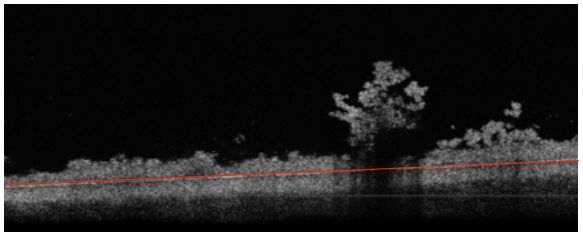
OCT is suitable to monitor meso-scale biofilm structure AND complementary to CLSM

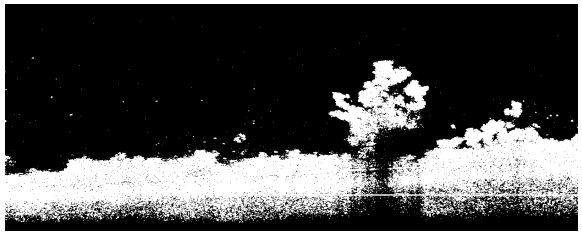
Quantification of OCT images

#1 Image recording using OCT



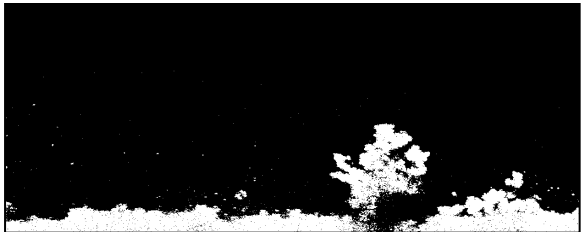
#2 Membrane detection (automatic or manual). If automatic, filtering + maximum intensity detection



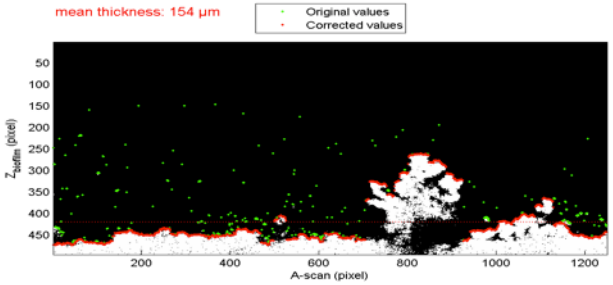


#3 Thresholding (Triangle method) Zack et al., 1977

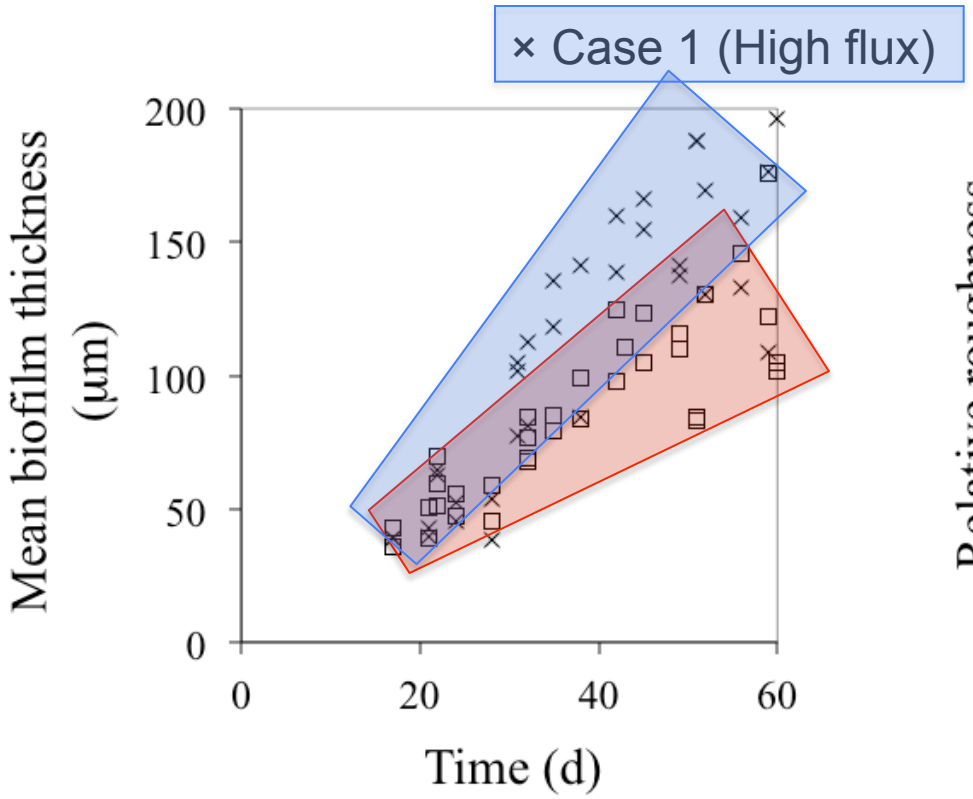
#4 Cropping and re-sizing (Wagner et al., 2010)

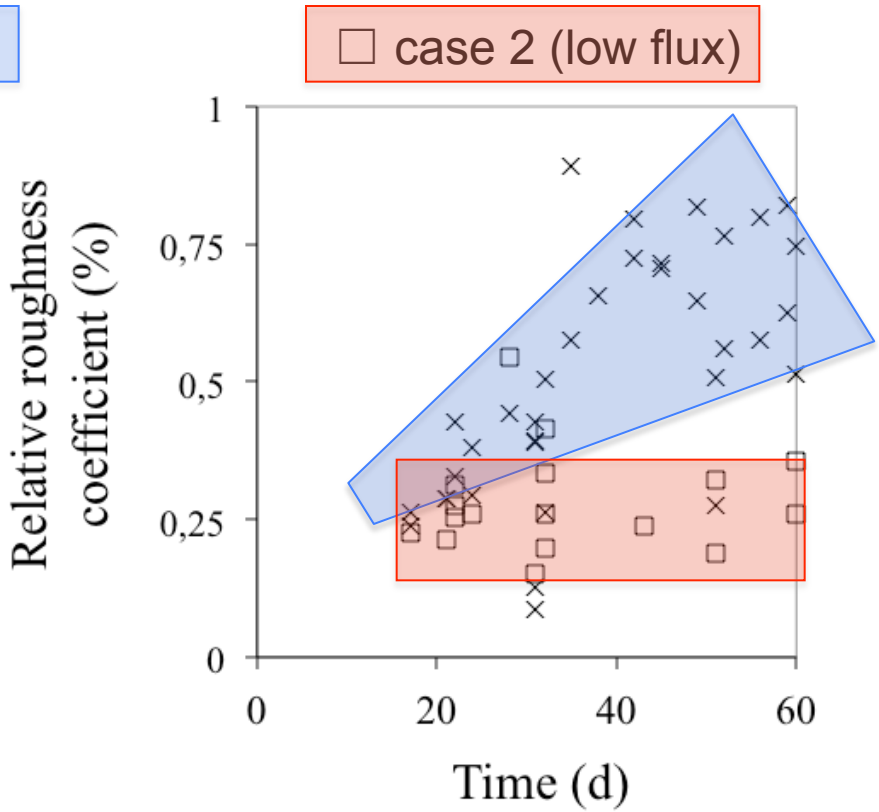


#5 Quantification after outlier detection

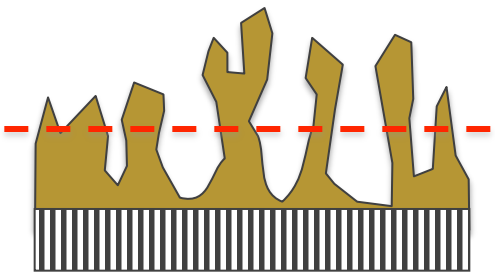


Quantification of OCT images reveals changes in the biofilm structure

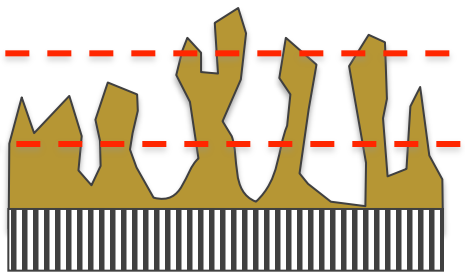




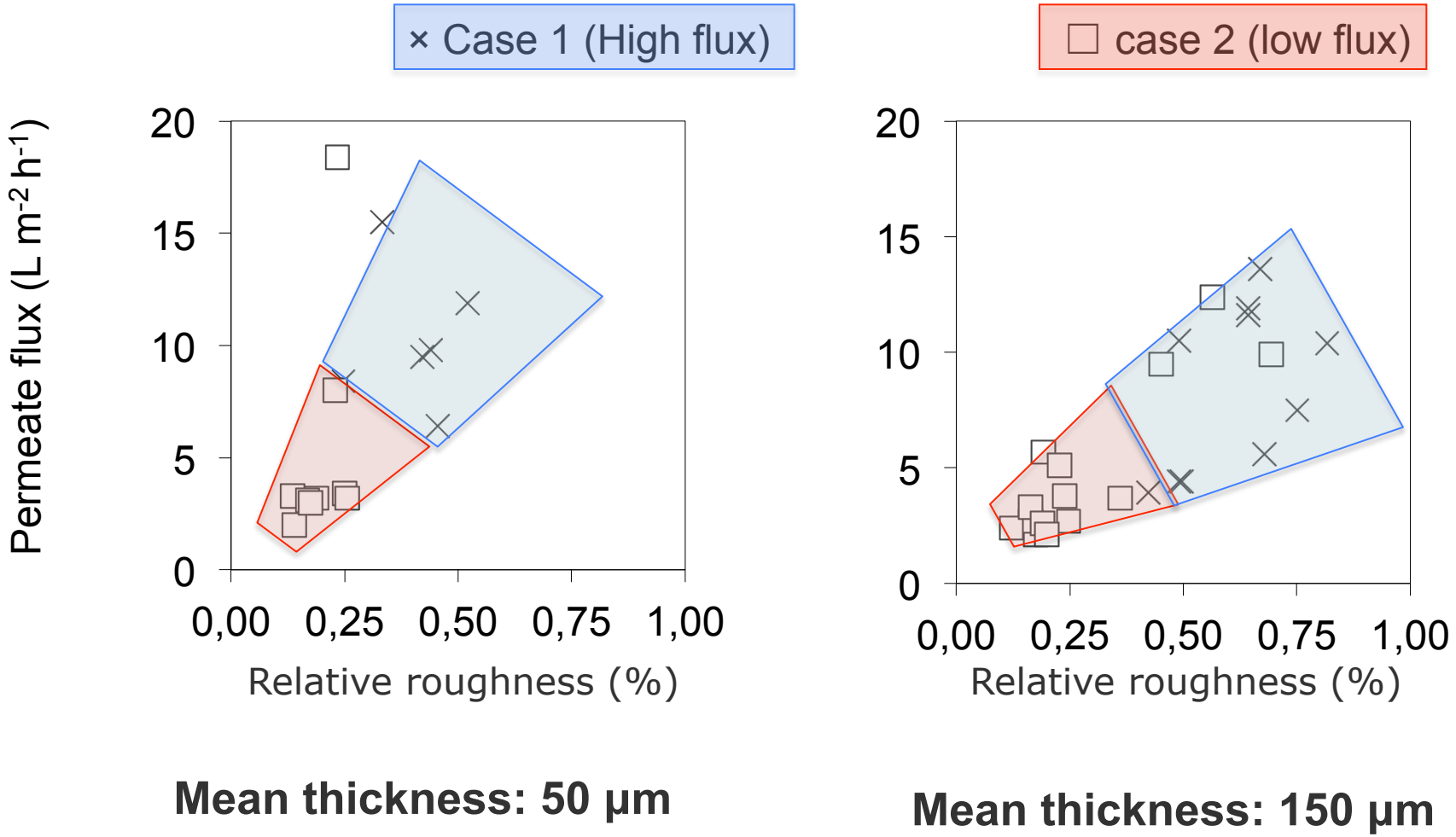
Z_mean



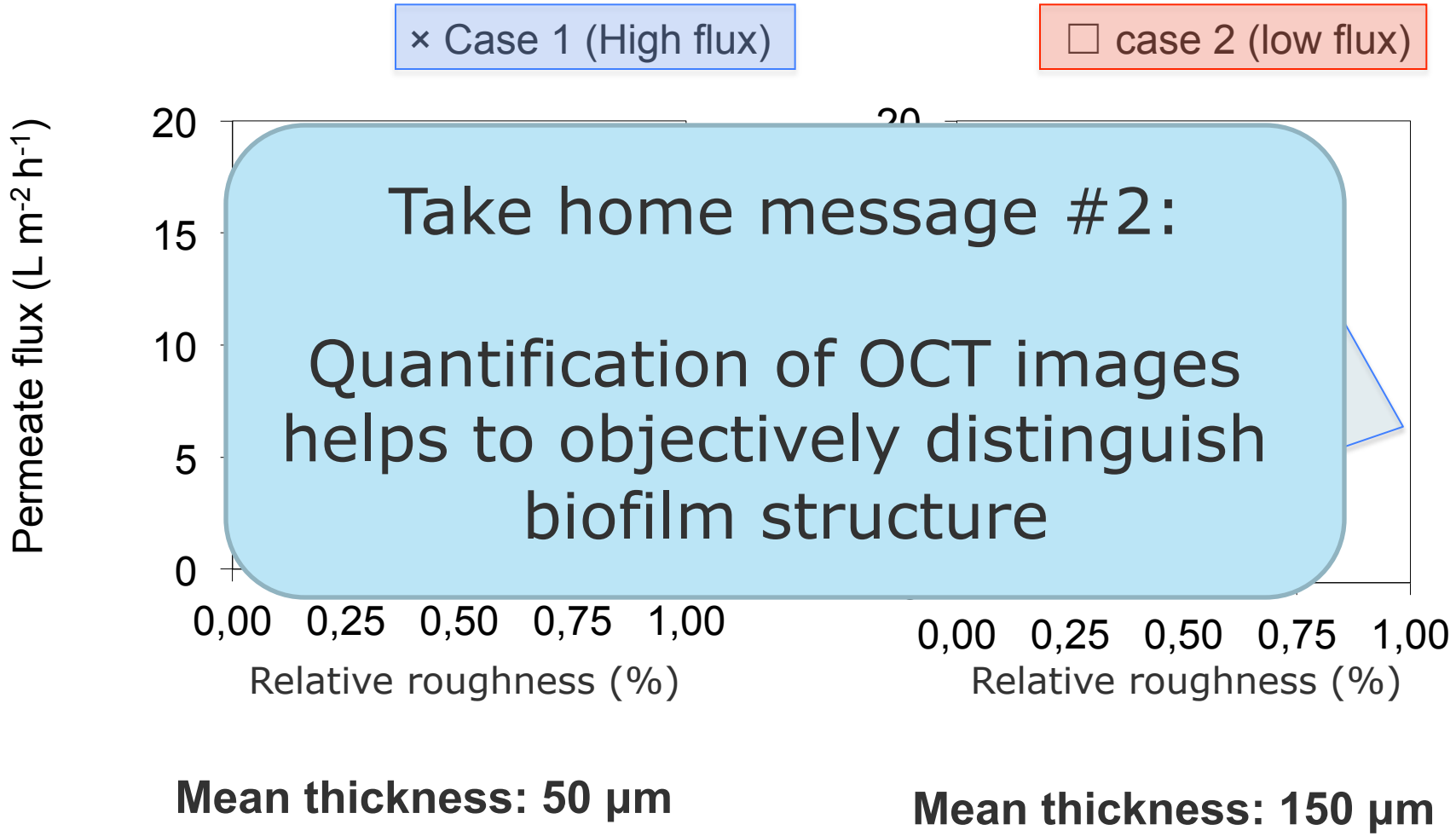
R_a'



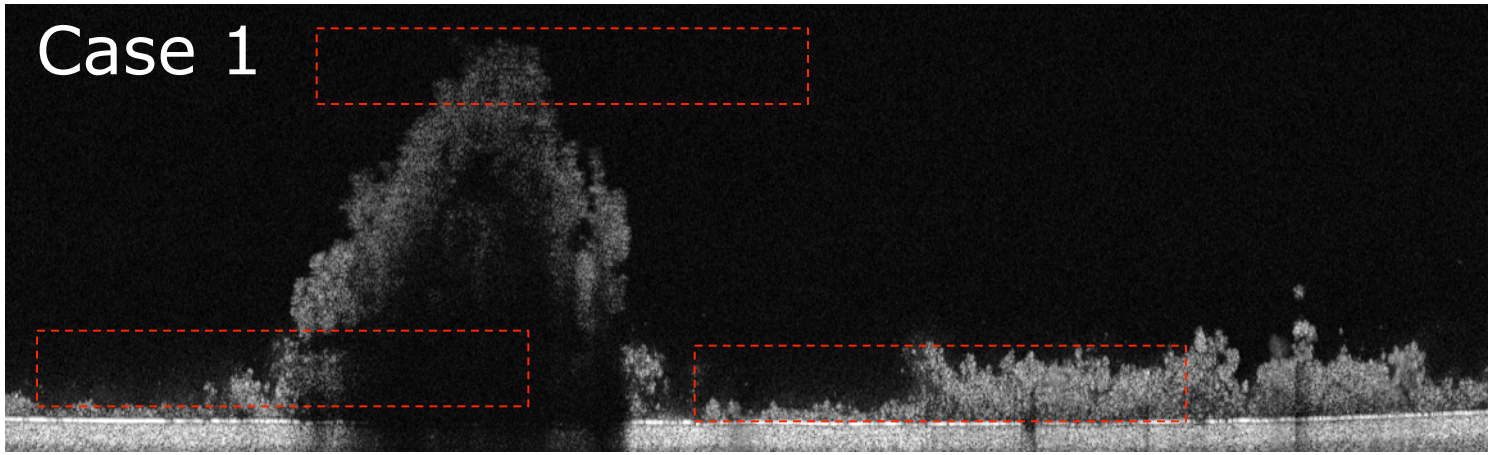
Meso-scale biofilm structure influences filtration performance

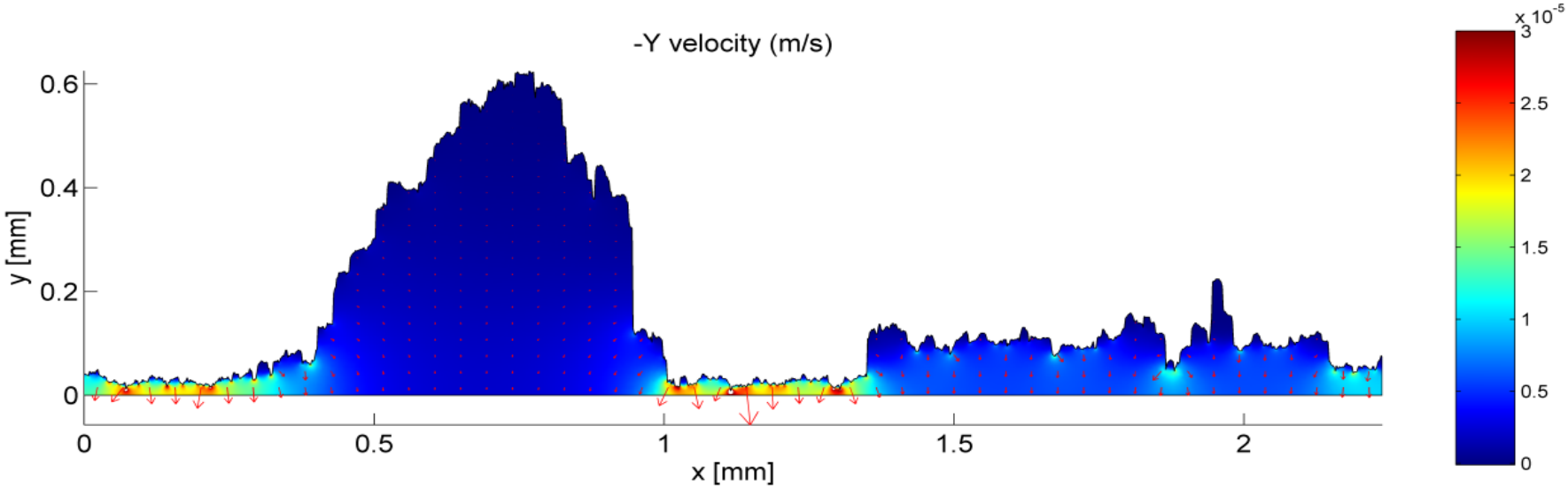


Meso-scale biofilm structure influences filtration performance



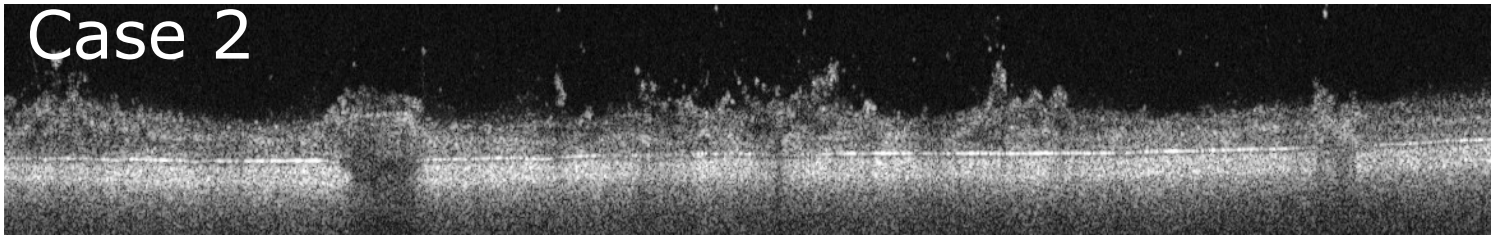
How does a heterogeneous biofilm structure influence the flux?

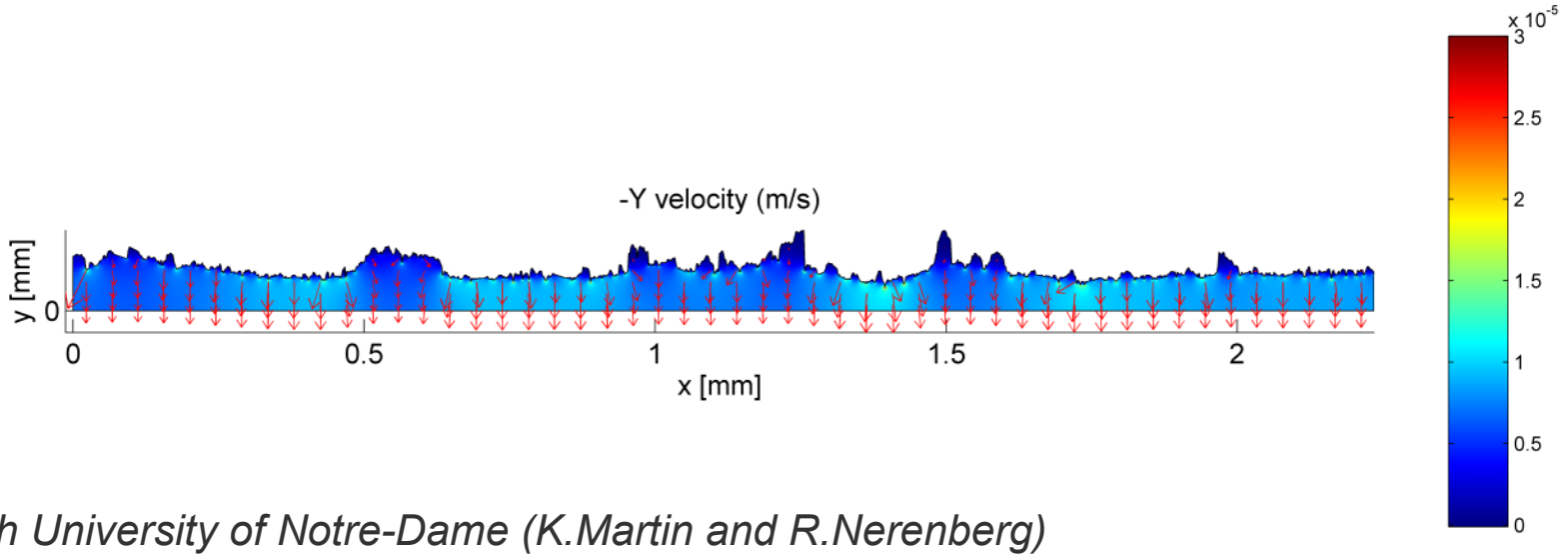




Coll. with University of Notre-Dame (K.Martin and R.Nerenberg)

Combining OCT with COMSOL® explains flow distribution…





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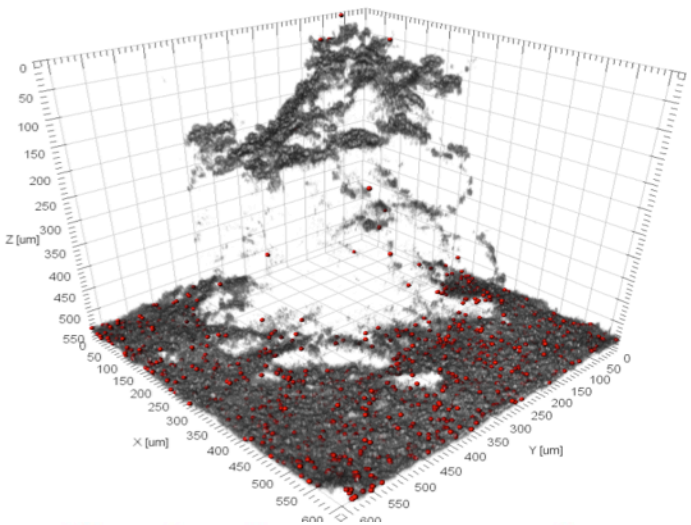
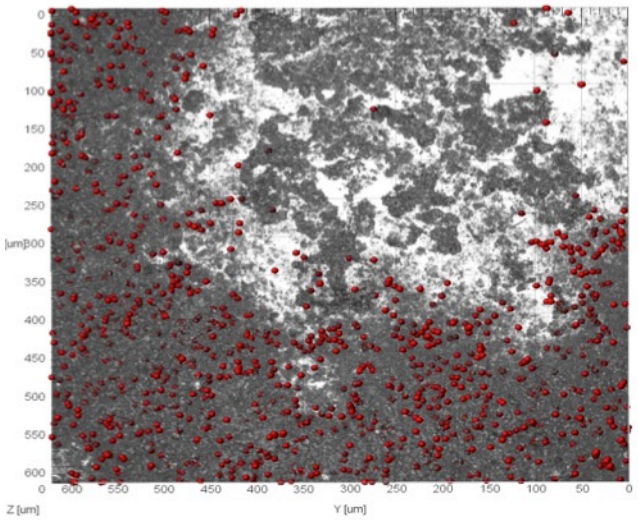
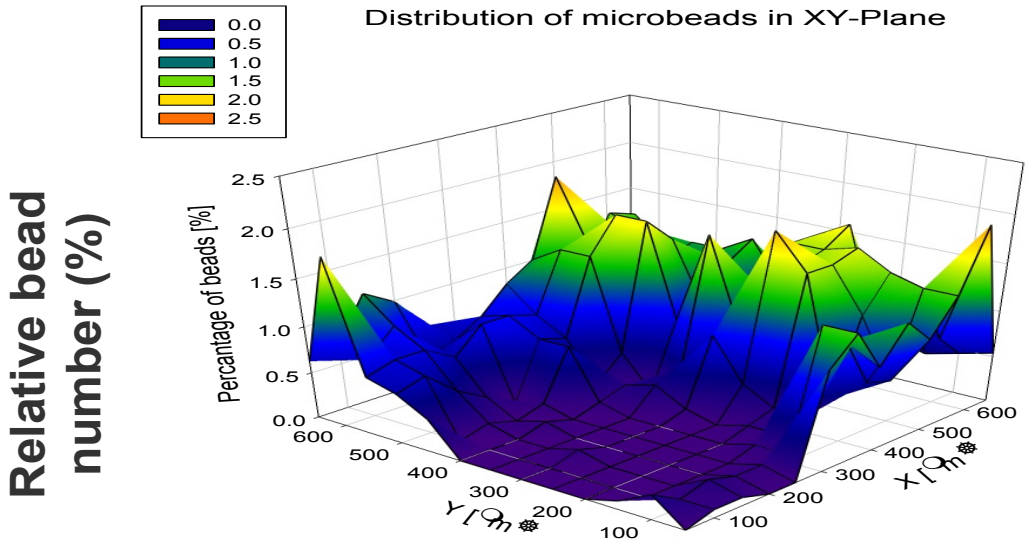
Fluorescent microspheres and CLSM…



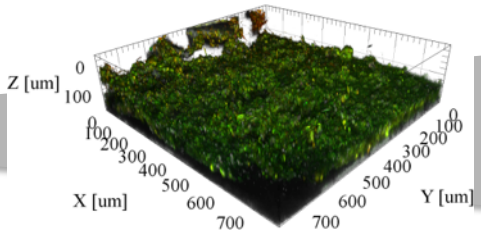




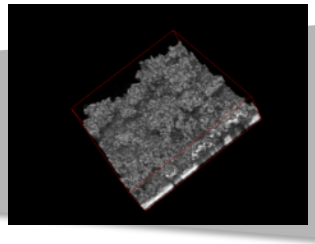
Both numerical and experimental results confirm that the more heterogeneous the biofilm structure the higher the permeate flux

MS thesis of M.Grau (2010)

Conclusions



(a) CLSM (micro-scale): **Similar biofilm structures**



(b) OCT (Meso-scale): **Different biofilm structures** (thickness, roughness, etc)

(c) Flow cell (Laboratory-scale): **Different fluxes**

(d) GDM system (full scale): **Different fluxes**

Monitoring and quantification of meso-scale biofilm structure using Optical Coherence Tomography provides relevant information to better understand biofilm systems, e.g., GDM filtration. Greater potential of OCT when combined with complementary analytical tools and integrated in a multi-scale approach.