

**Título** Turbulence Model Influence in the Breaking Dam Problem

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**Tipo de Producto** Ponencia resumen

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Código del Proyecto y Título del Proyecto

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A14T09 - Modelado y simulación de flujos de frontera libre de fluidos reactivos no-newtonianos  
Responsable del Proyecto

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Pablo Caron

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Línea

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Fluido Dinámica Computacional (CFD)

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Área Temática

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Modelado y Simulación (MyS)

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Fecha

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Abril 2015

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**INTEC**

Instituto de Tecnología

**UADE** 

# Turbulence Model Influence in the Breaking Dam Problem

UADE A14T08: Fluidodinámica Computacional Simulación y Experimentos

UADE A14T09: Modelado y Simulación de Flujos de Frontera Libre de Fluidos Reactivos No-Newtonianos

Pablo Caron<sup>[1]</sup>, Marcela Cruchaga<sup>[2]</sup>, Axel Larreteguy<sup>[1]</sup>

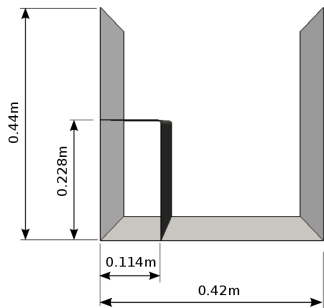
[1] Instituto de Tecnología - Universidad Argentina de la Empresa

[2] Universidad de Santiago de Chile

1st. Pan-American Congress on Computational Mechanics  
April 27th-29th, 2015  
Buenos Aires - Argentina

- Breaking of a dam problem
  - Problem description
  - Objective
- Governing Equations
- Results
  - Snapshots
  - Liquid interface evolution
- Conclusions

# Breaking of Dam Problem



Water properties

$$\rho = 1000 \text{ Kg/m}^3$$

$$\nu = 1 \times 10^{-6} \text{ m}^2/\text{s}$$

Air properties

$$\rho = 1 \text{ Kg/m}^3$$

$$\nu = 1 \times 10^{-3} \text{ m}^2/\text{s}$$

Experiments: Cruchaga et al. Collapse of a liquid column: Numerical simulation and experimental validation. *Computational Mechanics*, 2007; 39(4):453476

Simulations: OpenFOAM 2.2.1 (interFoam)

# Governing Equations

Indicator function

$$\frac{\partial \gamma}{\partial t} + \nabla \cdot (\mathbf{U}\gamma) + \nabla \cdot (\mathbf{U}_r\gamma(1 - \gamma)) = 0$$

Weighted properties

$$\rho = \rho_l\gamma + \rho_g(1 - \gamma) \quad \mu = \mu_l\gamma + \mu_g(1 - \gamma)$$

Momentum equations

$$\begin{aligned} \nabla \cdot \mathbf{U} &= 0, \\ \frac{\partial(\rho\mathbf{U})}{\partial t} + \nabla \cdot (\rho\mathbf{U}\mathbf{U}) &= -\nabla p + \rho\mathbf{g} + \mathbf{f}_\sigma + \nabla \cdot \boldsymbol{\tau} \end{aligned}$$

where:  $\boldsymbol{\tau} = \mu_{eff}[\nabla\mathbf{U} + (\nabla\mathbf{U})^T]$ ,  $\mu_{eff} = \rho(\nu_t + \nu)$ , and  $\nu = \mu/\rho$

Turbulence models selected: Spalart-Allmaras and  $k - \varepsilon$

## 1 Snapshots

- Mesh size convergence without turbulence model
- Mesh size convergence with  $k - \varepsilon$  turbulence model
- Turbulence model comparison ( $k - \varepsilon$  vs Spalart-Allmaras)

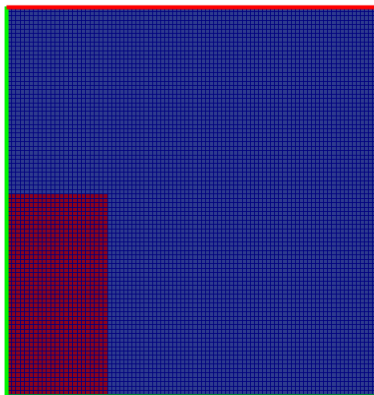
## 2 Interface position

- Interface detection strategy
- Positions without turbulence model
- Positions with  $k - \varepsilon$  turbulence model

## 3 Tridimensional Results

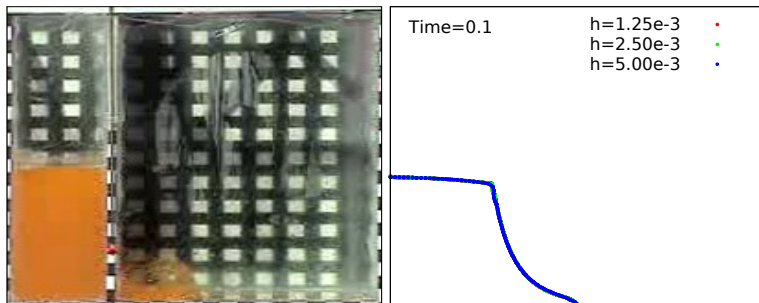
# Results: Mesh details

Mesh size h [m]	Hor. × Vert.	Total
$1.25 \times 10^{-3}$	$355 \times 353$	7921
$2.50 \times 10^{-3}$	$177 \times 178$	31506
$5.00 \times 10^{-3}$	$89 \times 89$	125315



# Results 1: Mesh convergence analysis for 2D cases

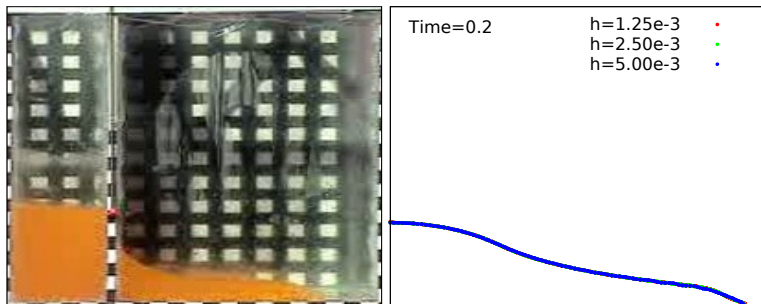
Simulations without turbulence model enabled.





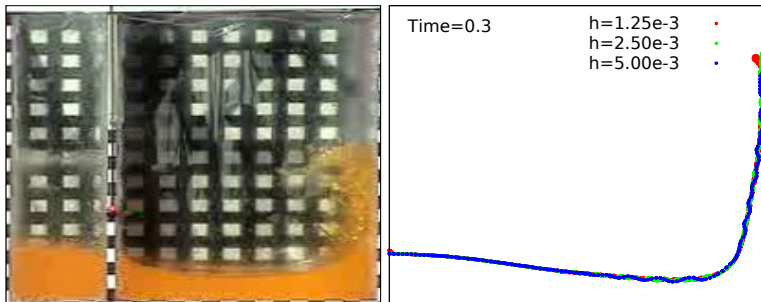
# Results 1: Mesh convergence analysis for 2D cases

Simulations without turbulence model enabled.



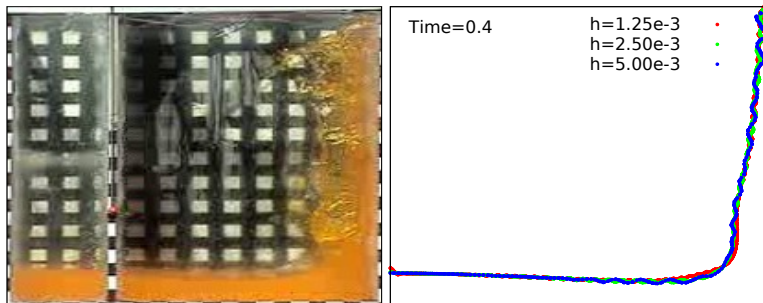
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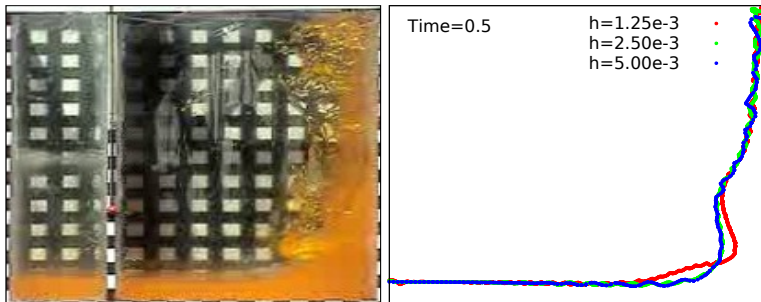
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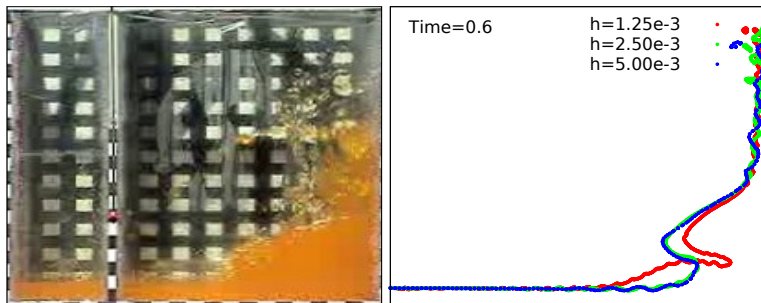
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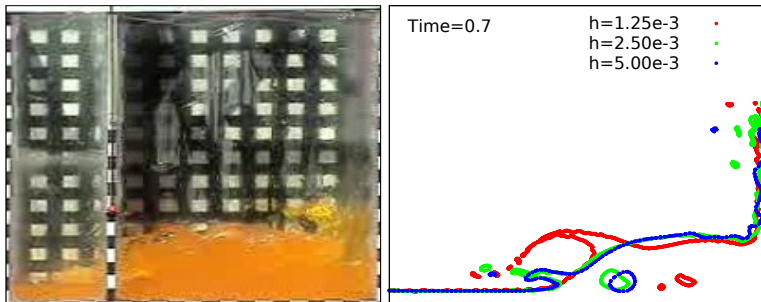
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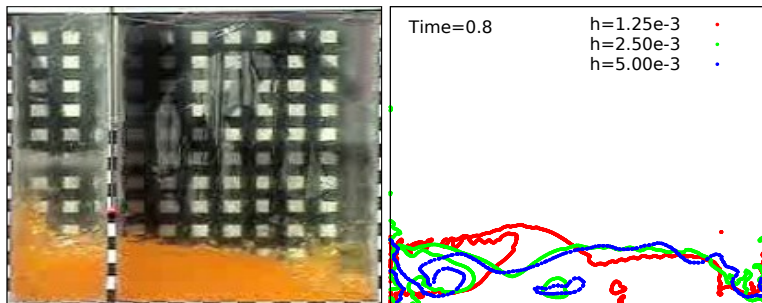
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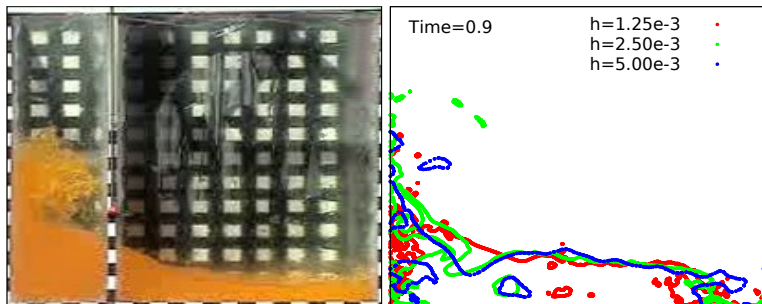
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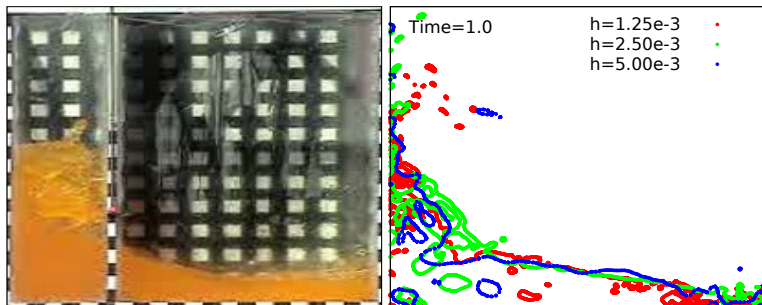
Simulations without turbulence model enabled.





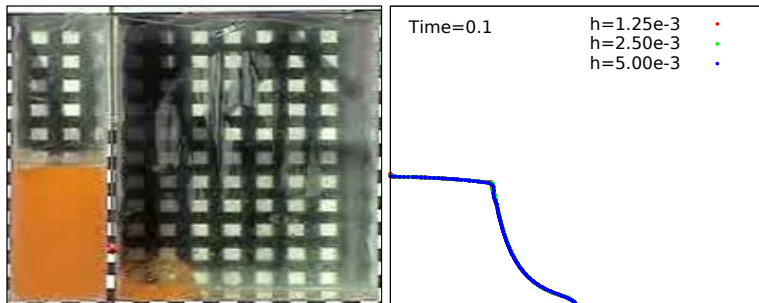
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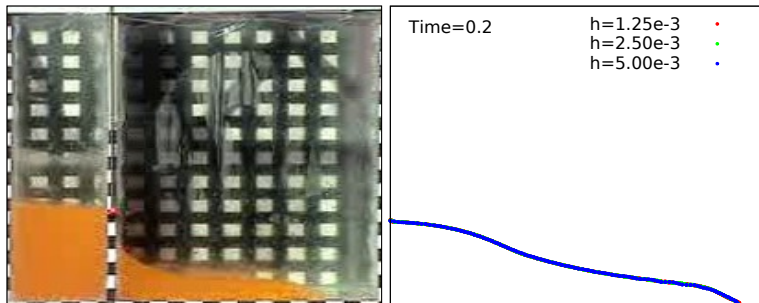
# Results 1: Mesh convergence analysis for 2D cases

Simulations with  $k - \varepsilon$  turbulence model



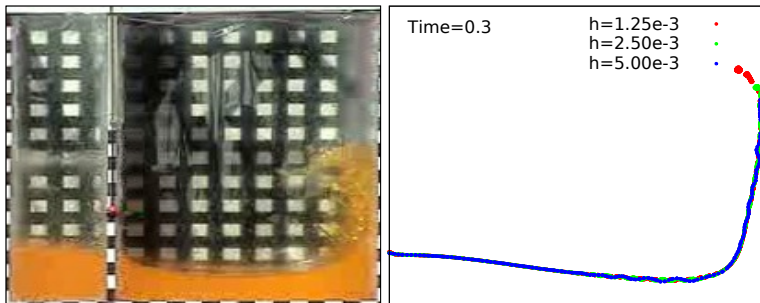
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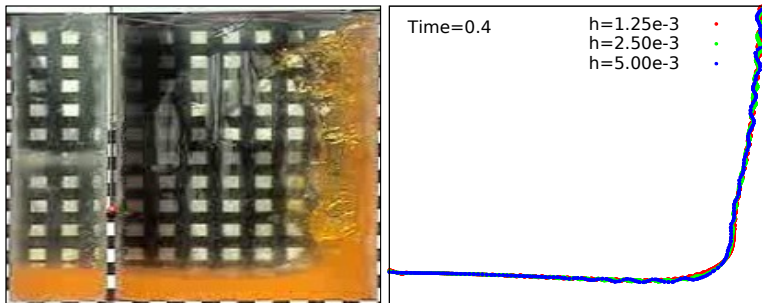
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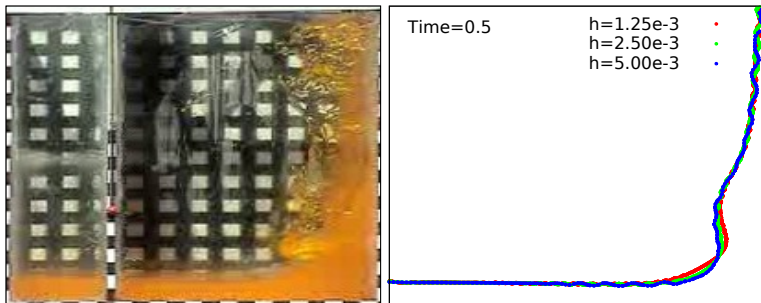
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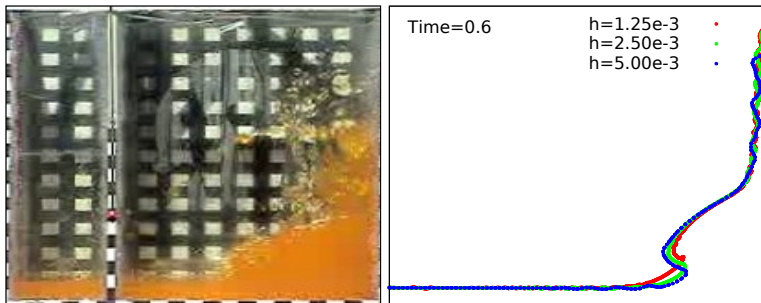
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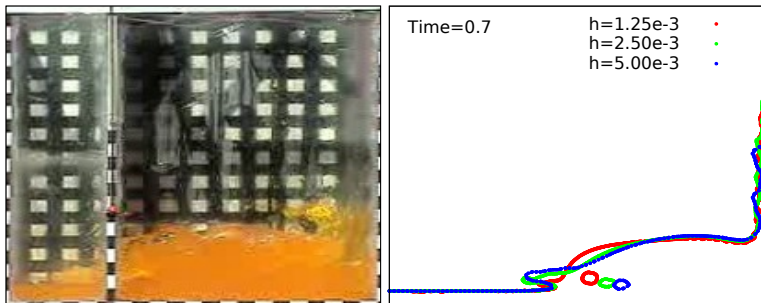
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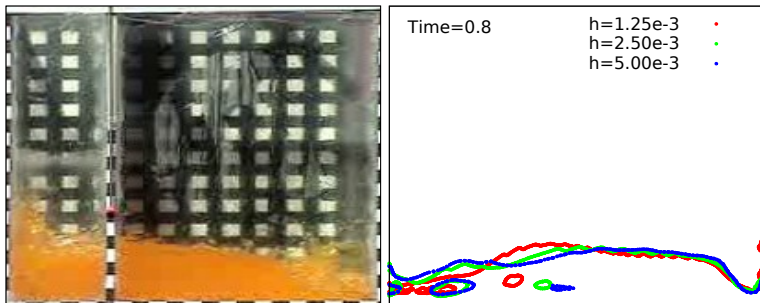
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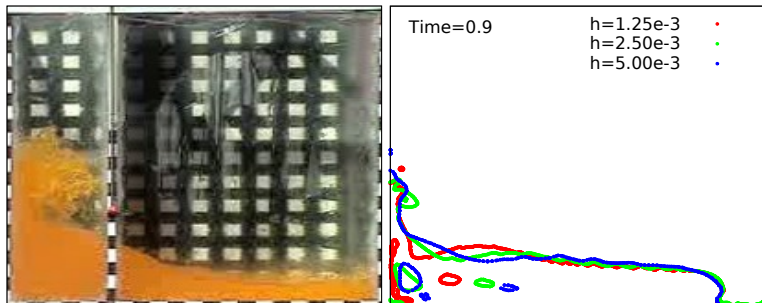
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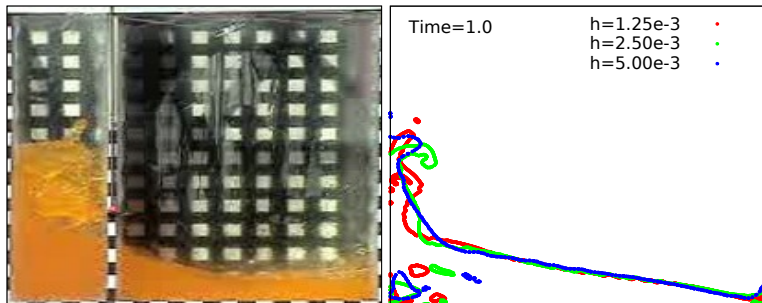
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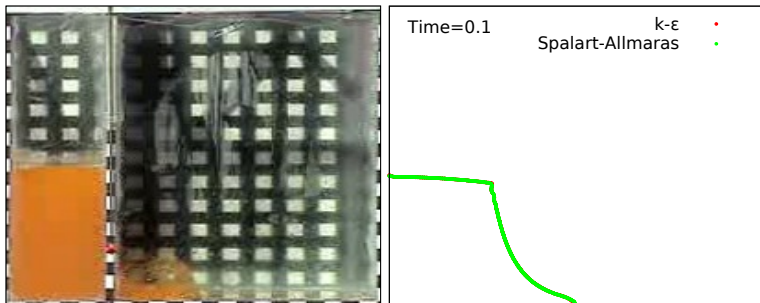
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Simulations with  $k - \varepsilon$  turbulence model



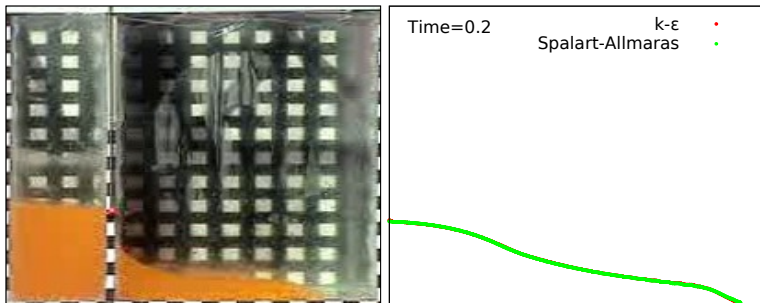
# Results 1: Turbulence model comparison

Simulation details:  $h = 2.5 \times 10^{-3}$



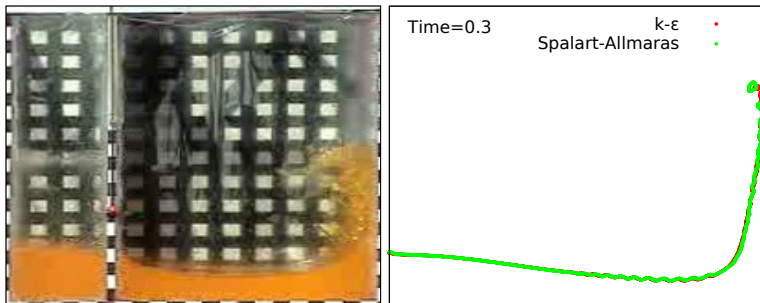
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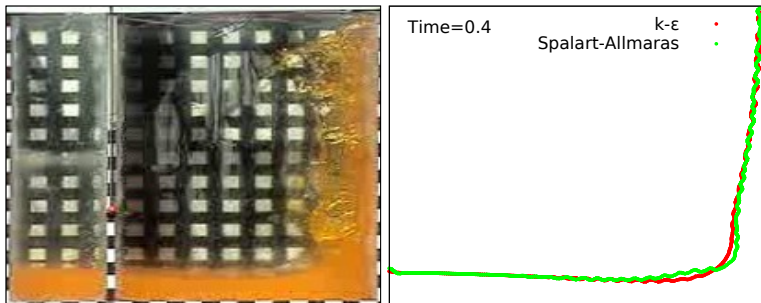
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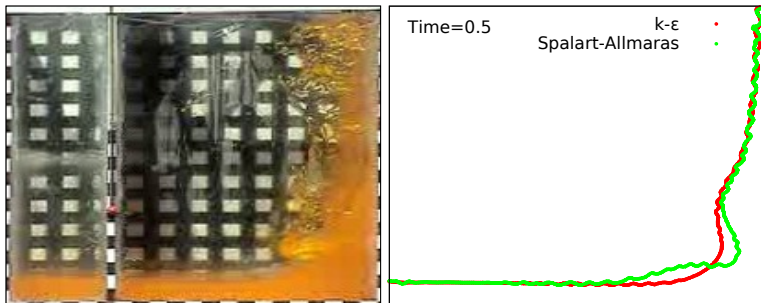
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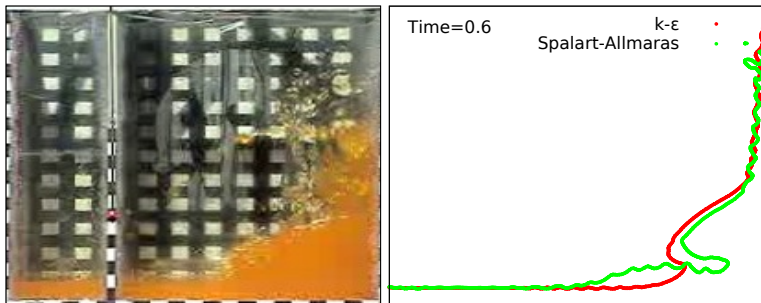
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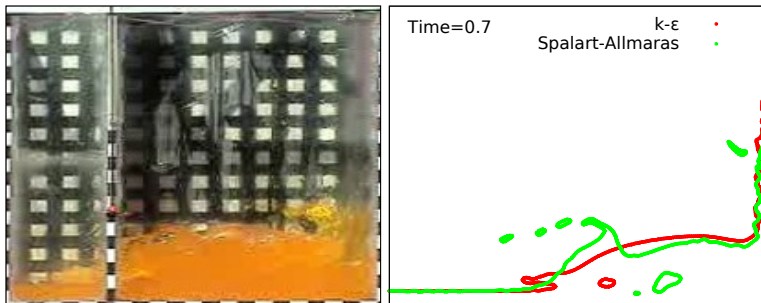
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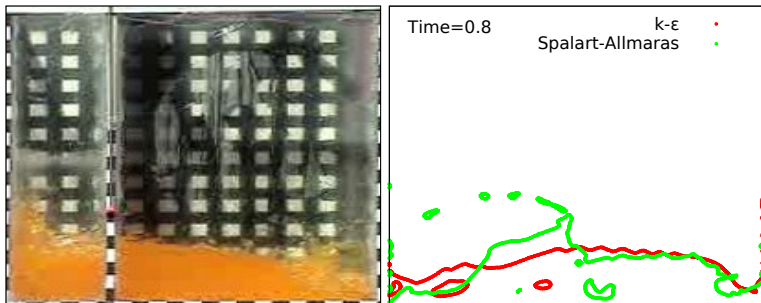
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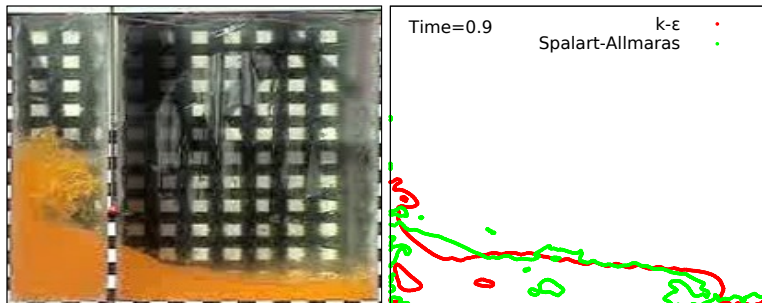
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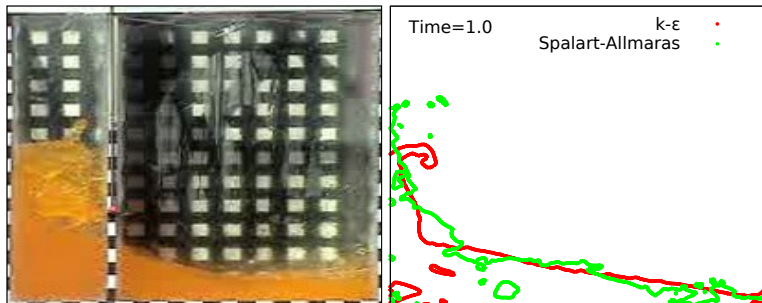
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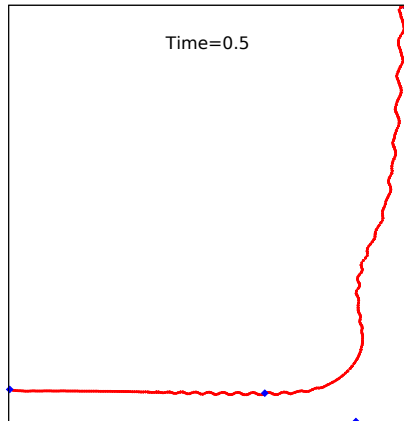
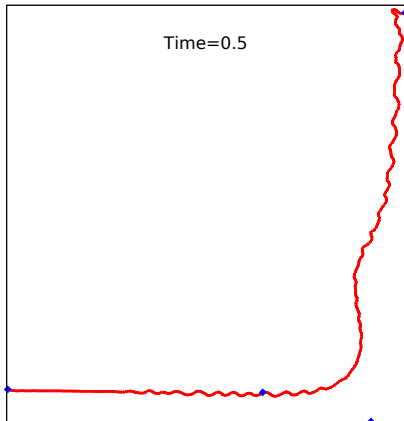
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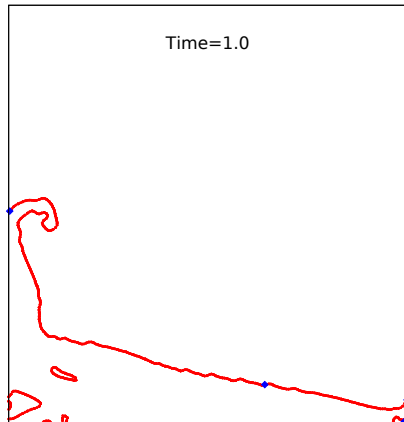
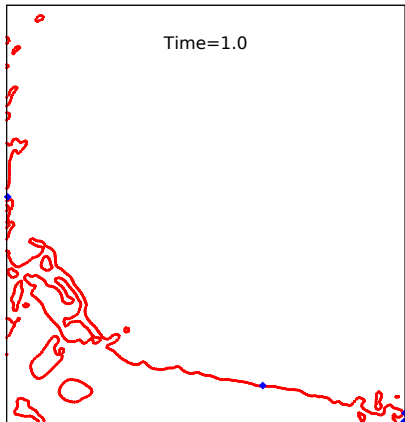
# Results 2: Interface evolution

Interface identification for simulations with and without turbulence model.



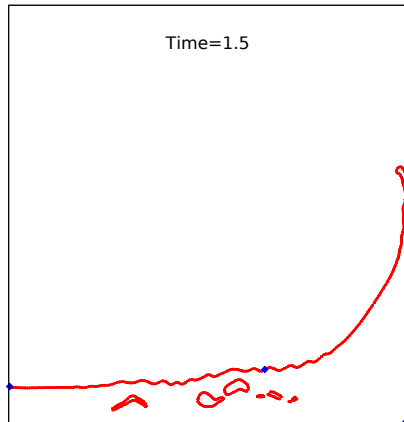
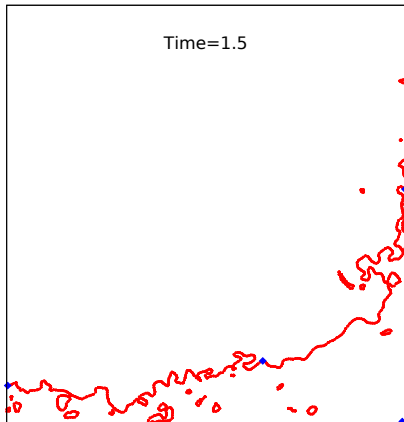
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## Results 2: Interface evolution

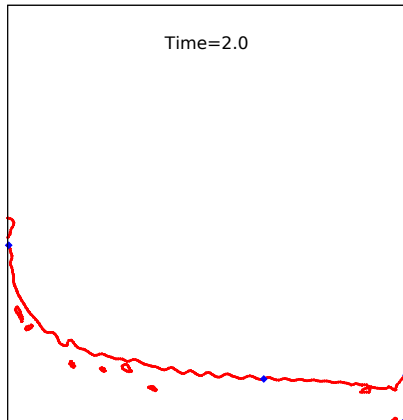
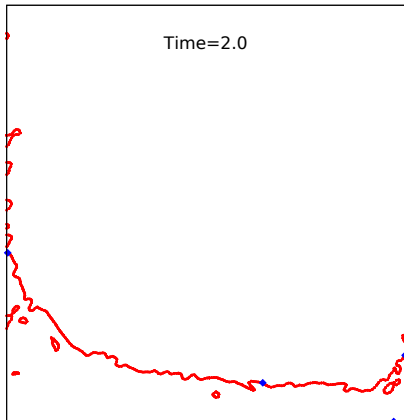
Interface identification for simulations with and without turbulence model.





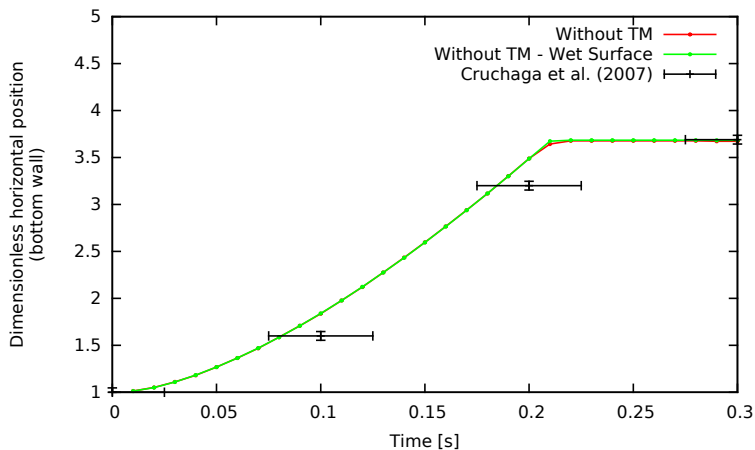
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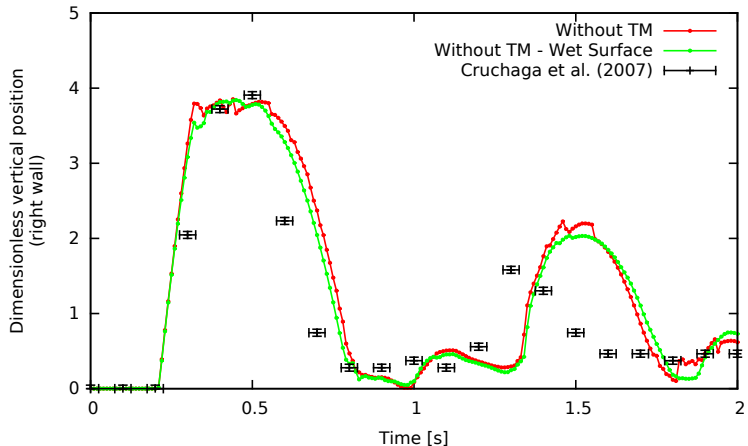
# Results 2: Interface evolution

## Interface without turbulence model over the Floor



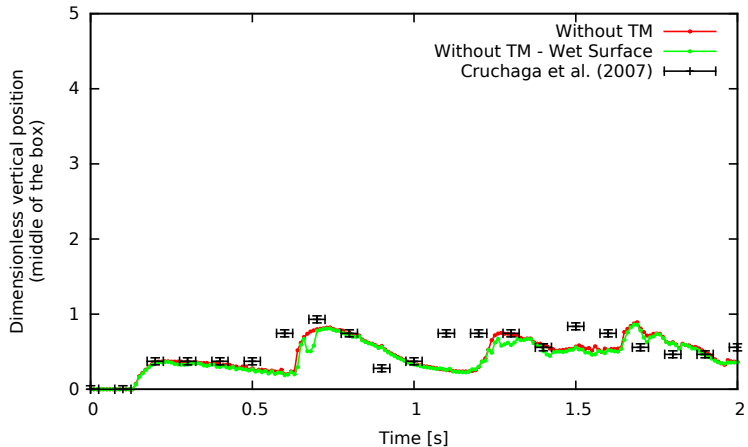
## Results 2: Interface evolution

### Interface without turbulence model over the right wall



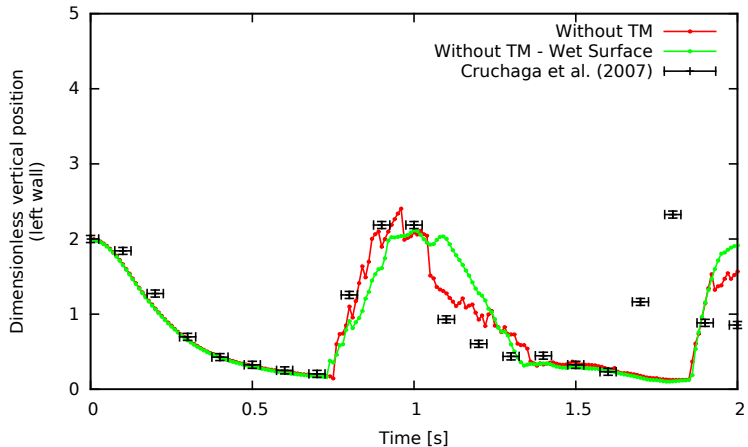
## Results 2: Interface evolution

Interface without turbulence model over the middle vertical line



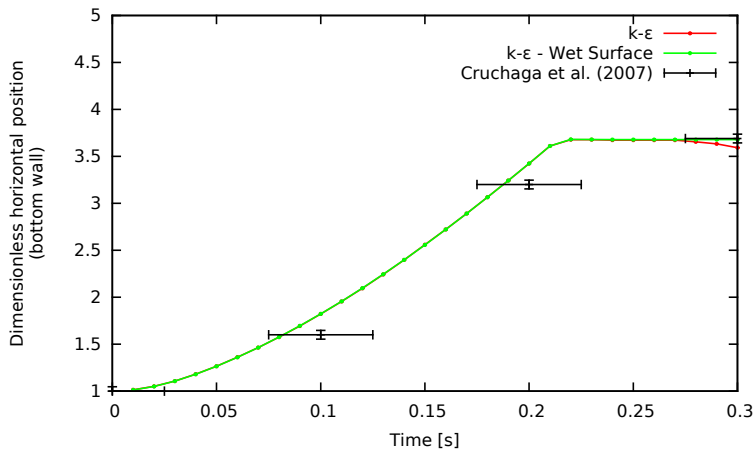
# Results 2: Interface evolution

## Interface without turbulence model over the left wall



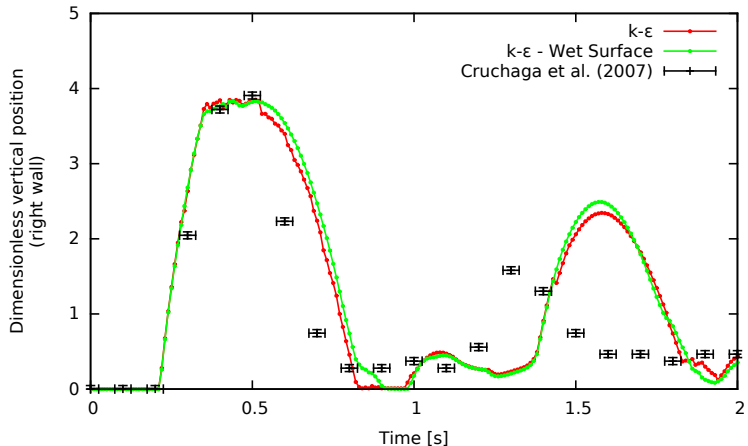
# Results 2: Interface evolution

Interface with  $k - \varepsilon$  turbulence model over the Floor



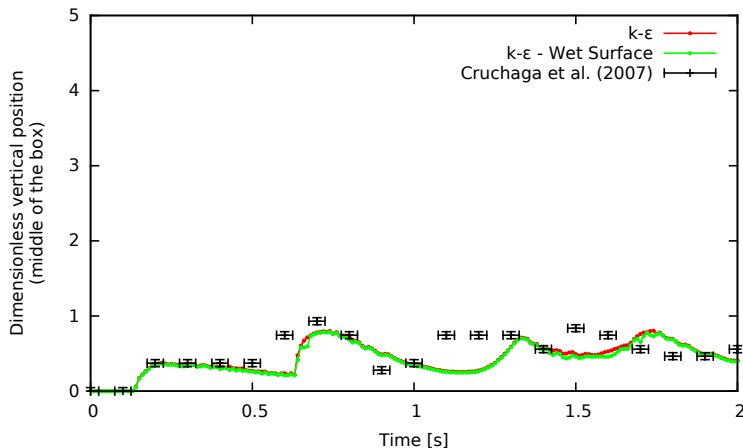
# Results 2: Interface evolution

Interface with  $k - \varepsilon$  turbulence model over the right wall



## Results 2: Interface evolution

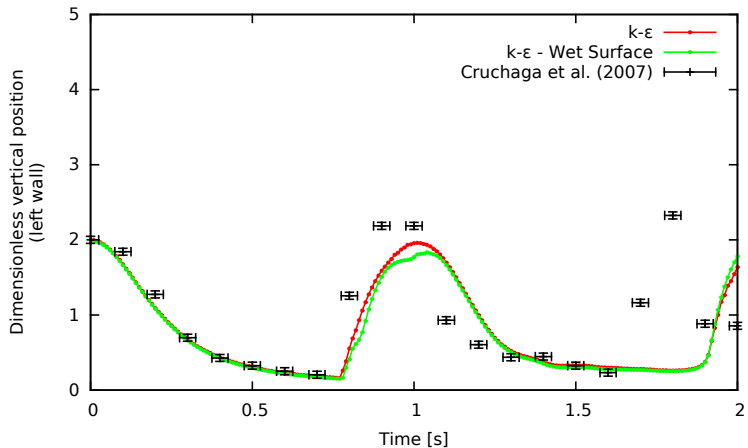
Interface with  $k - \varepsilon$  turbulence model over the middle vertical line





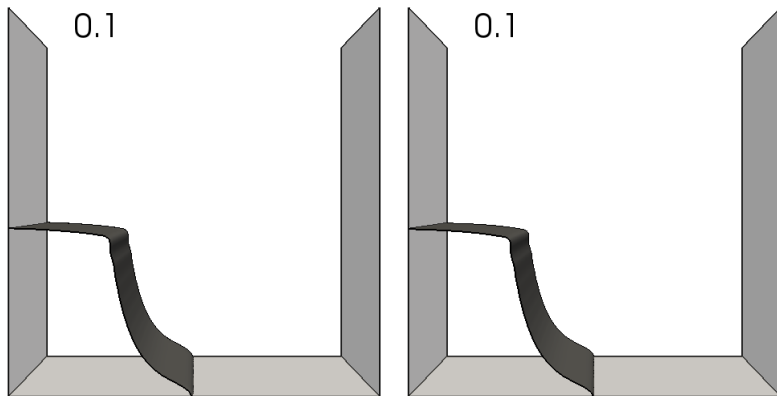
# Results 2: Interface evolution

Interface with  $k - \varepsilon$  turbulence model over the left wall



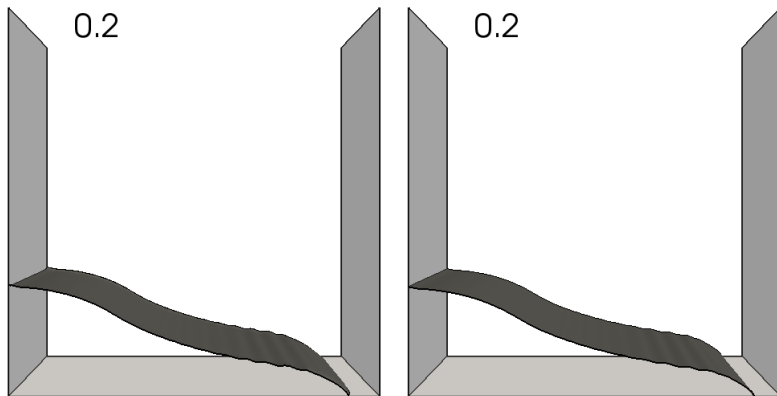
# Results 3: 3 dimensional

3D simulations with and without slip boundary condition over front and back  
Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$



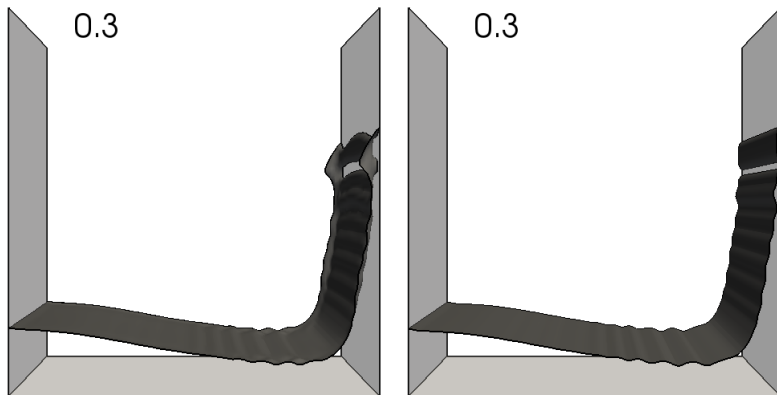
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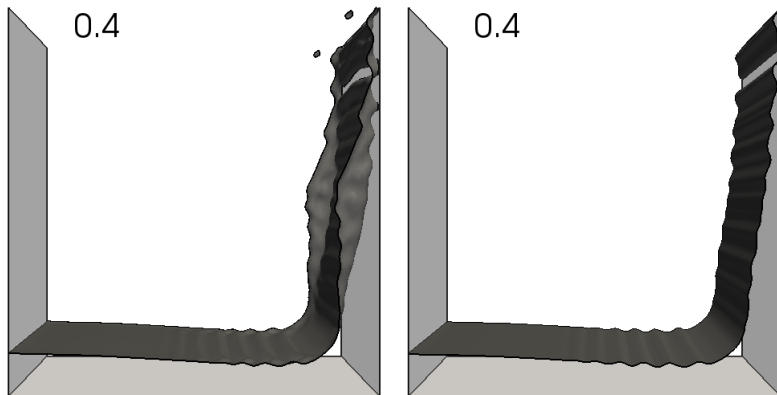
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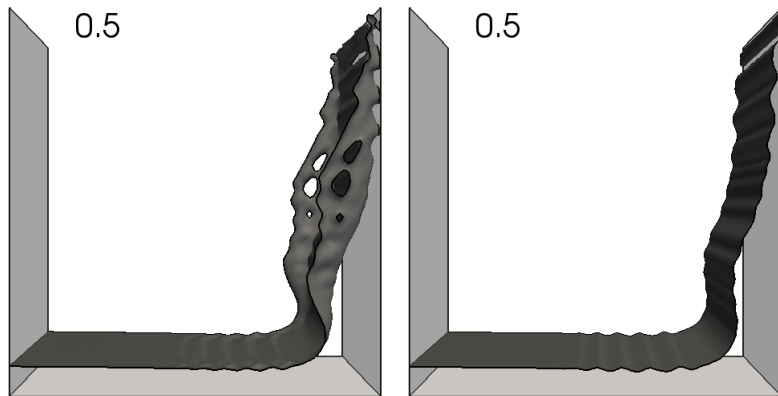
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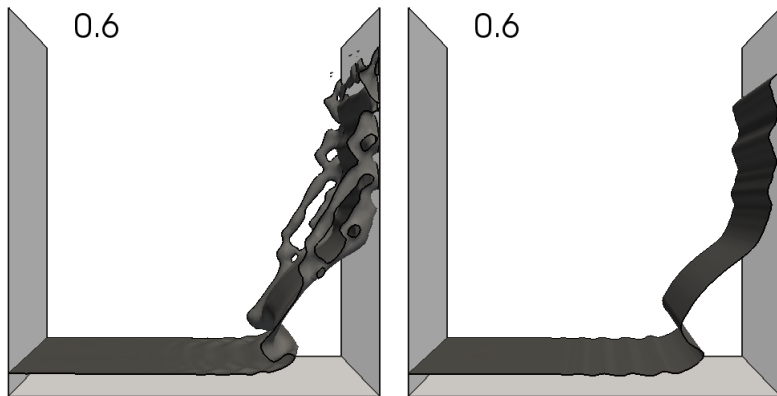
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3D simulations with and without slip boundary condition over front and back Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$



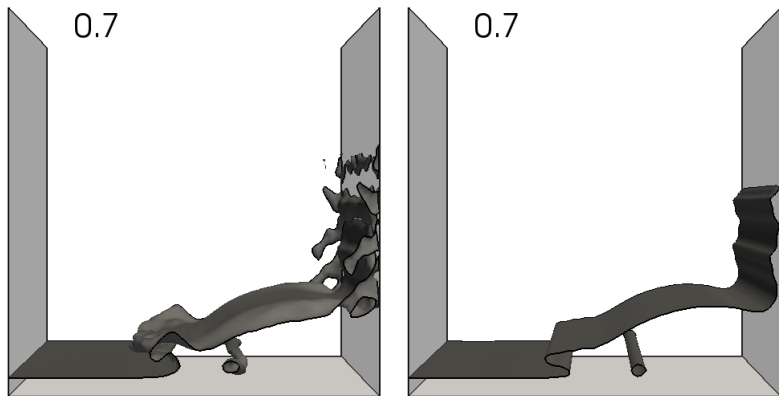
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3D simulations with and without slip boundary condition over front and back Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$



## Results 3: 3 dimensional

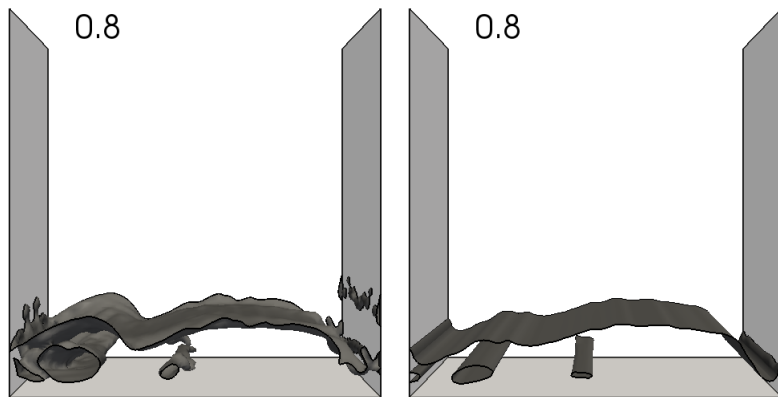
3D simulations with and without slip boundary condition over front and back Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$





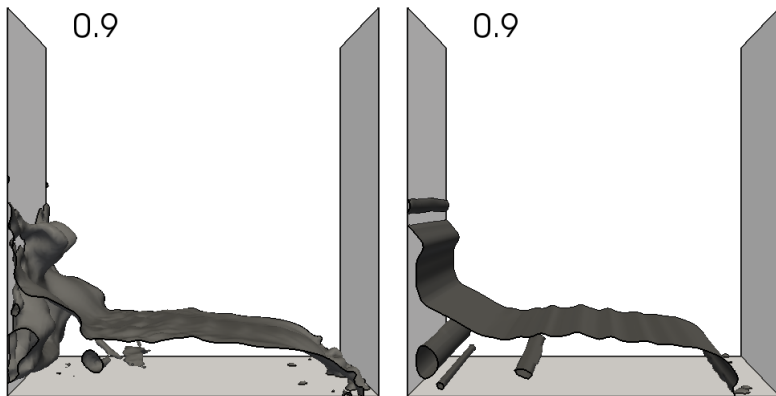
## Results 3: 3 dimensional

3D simulations with and without slip boundary condition over front and back  
Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$



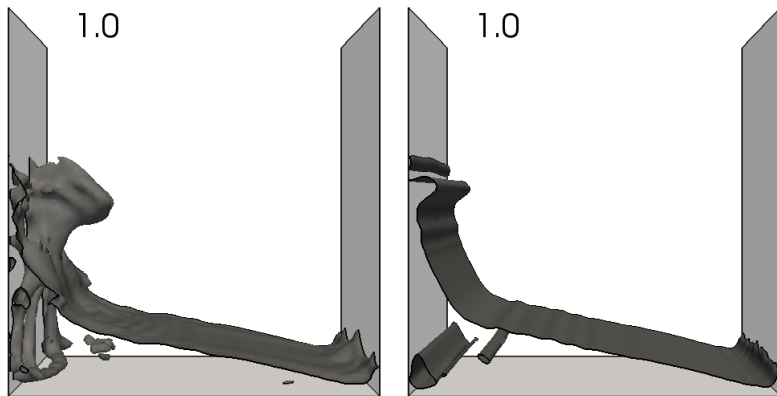
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## Results 3: 3 dimensional

3D simulations with and without slip boundary condition over front and back Simulation details:  $k - \varepsilon$  turbulence model,  $h = 5 \times 10^{-3}$





# Thank you

## Questions?



# EXTRAS

# Simulation Details

Case description	Time Step [s]			Mesh Size
	Min	Max	Mean	
Without turbulence model	$1.1 \times 10^{-5}$	$1.2 \times 10^{-3}$	$5.4 \times 10^{-5}$	125315
	$3.1 \times 10^{-5}$	$1.0 \times 10^{-3}$	$1.1 \times 10^{-4}$	31506
	$5.7 \times 10^{-5}$	$1.0 \times 10^{-3}$	$2.1 \times 10^{-4}$	7921
$k - \varepsilon$ turbulence model	$2.1 \times 10^{-5}$	$1.6 \times 10^{-3}$	$9.8 \times 10^{-5}$	125315
	$4.0 \times 10^{-5}$	$1.0 \times 10^{-3}$	$1.7 \times 10^{-4}$	31506
	$6.7 \times 10^{-5}$	$1.0 \times 10^{-3}$	$2.8 \times 10^{-4}$	7921
Spalart-Allmaras	$2.8 \times 10^{-5}$	$1.4 \times 10^{-3}$	$1.2 \times 10^{-4}$	31506
Without TM + ST	$4.2 \times 10^{-5}$	$1.3 \times 10^{-3}$	$1.3 \times 10^{-4}$	31506
$k - \varepsilon$ TM + ST	$4.5 \times 10^{-5}$	$1.8 \times 10^{-3}$	$2.0 \times 10^{-4}$	31506
3D no-slip sides	$5.3 \times 10^{-5}$	$2.1 \times 10^{-3}$	$2.8 \times 10^{-4}$	372287
3D slip sides	$9.3 \times 10^{-5}$	$2.1 \times 10^{-3}$	$4.1 \times 10^{-4}$	372287