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PIV-PTV measurements of a tailings dam-break flow

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Outline

1. Introduction

2. Experimental Setup

3. Instrumentation

4. Measurement Techniques

5. Results

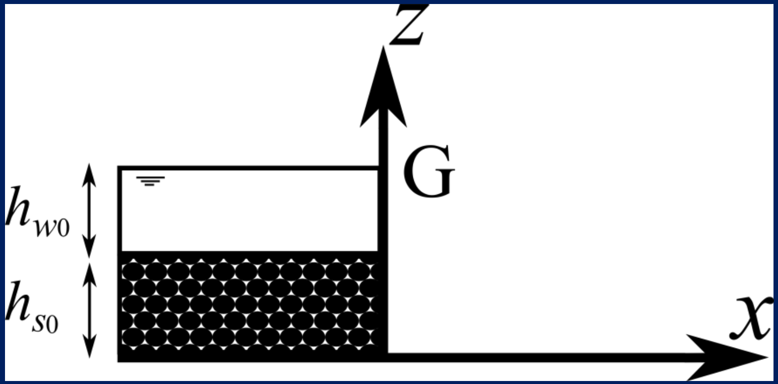
6. Conclusion & Future Work

1. Introduction

What is a tailings dam?

- Used to stock mining residuals
- Built with *in-situ* materials
- Source of heavy metals/pollutants
- More prone to accidents... (Rico et al. 2008)

Tailings dam:
http://www.groundtruthtrekking.org/static/uploads/photos/typical-mine-tailings-dam.jpg



1. Introduction

Tailings dam-break flow: Particular case of a dam-break flow

Source:http://northern-thailand-river.com/wp-content/uploads/2012/06/dam_break1.jpg

Source:http://photo.accuweather.com/photogallery/size/30320/South+fork+dam+breaks+1889

Source:http://upload.wikimedia.org/wikipedia/commons/thumb/0/06/BuffaloCreekArea.png/400px-BuffaloCreekArea.png

Source: http://salinapost.com/2012/11/20/breaking-news-grain-elevator-collapse-in-oakley/

1.2 Tailings dam failure

Application Example:

a) Buffalo Creek. USA. 1972

V ~ 500.000 m^3

b) 125 killed

c) 1121 injured

http://upload.wikimedia.org/wikipedia/commons/0/06/BuffaloCreekArea.png

1.2 Tailings dam failure

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b) 125 killed

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http://upload.wikimedia.org/wikipedia/commons/0/06/BuffaloCreekArea.png

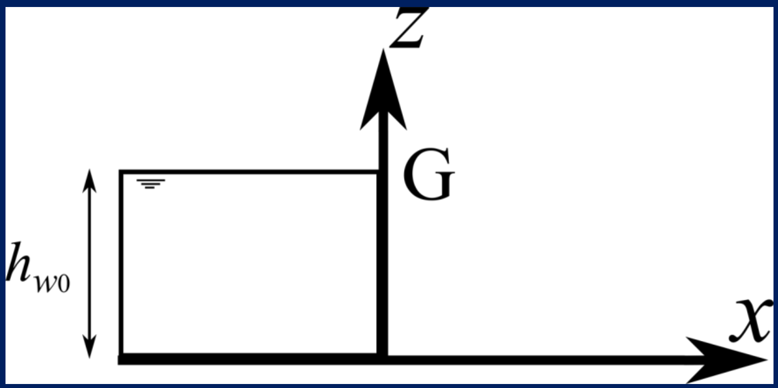
1. Introduction

Characteristics

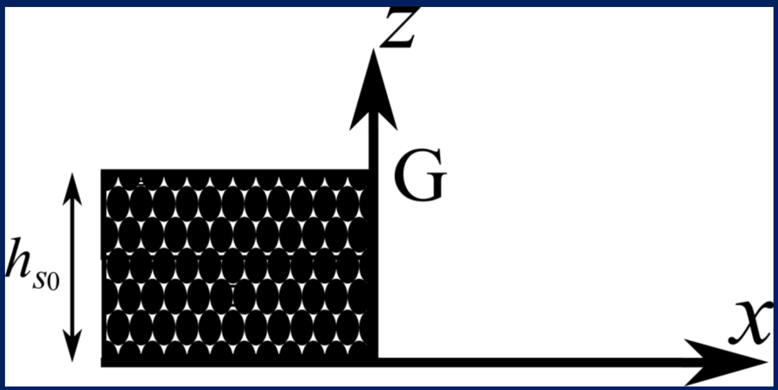
- Severe transient flow
- Sediment transport
- Geomorphological changes
- Near Field/Far Field Regimes
- Wide ranges of time and length scales
- Multiphase flow

How to classify these flows?

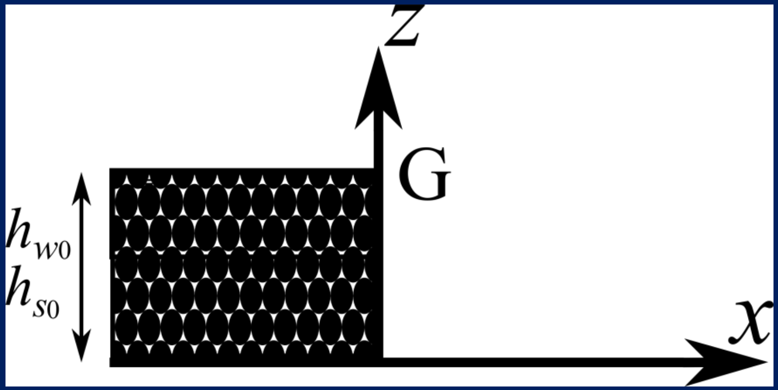
1.1 A Classification Hypothesis



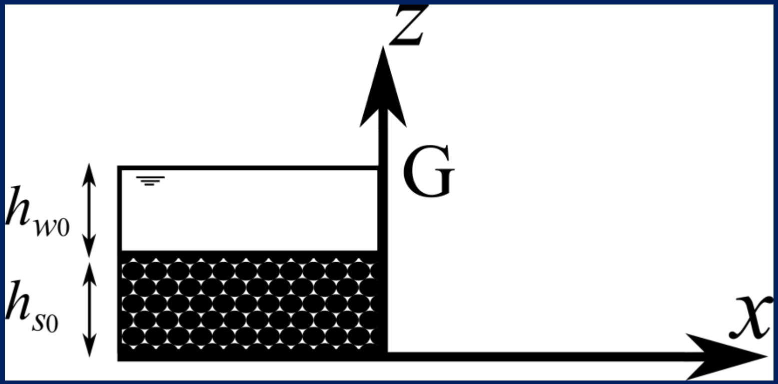
Hydrodynamic



Sedimentologic

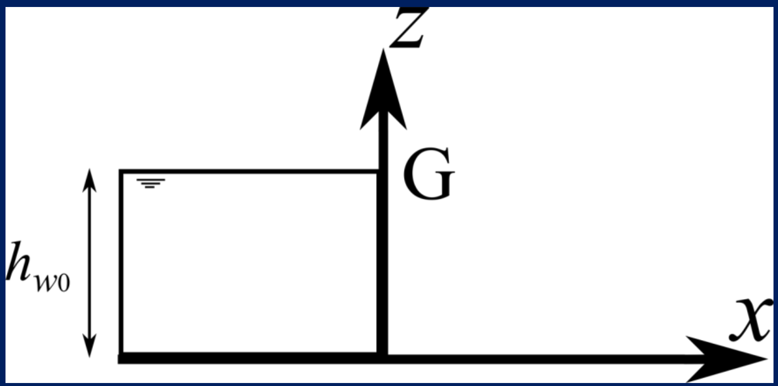


Under-saturated/Saturated

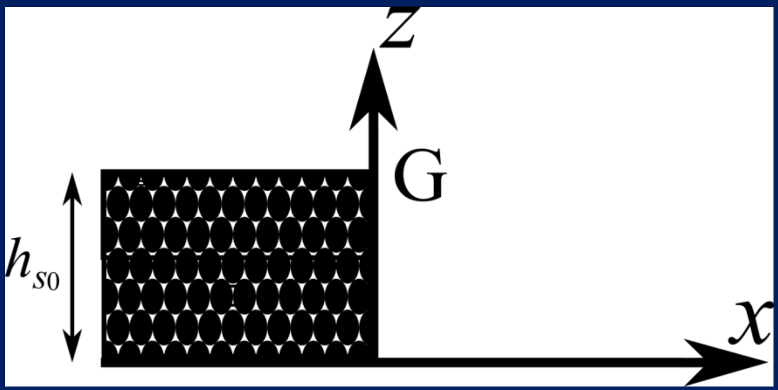


Submerged

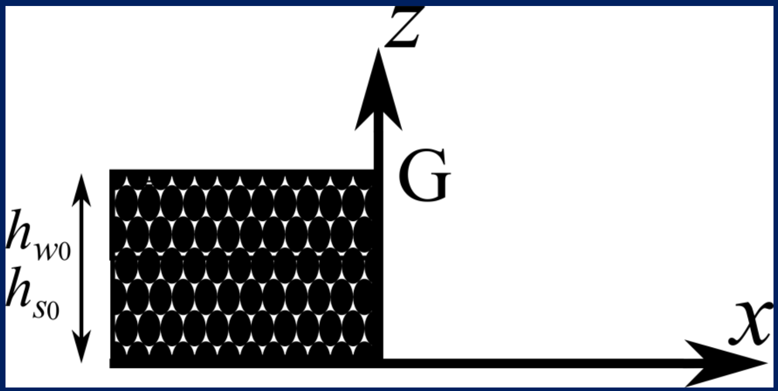
1.1 A Classification Hypothesis



Hydrodynamic



Sedimentologic



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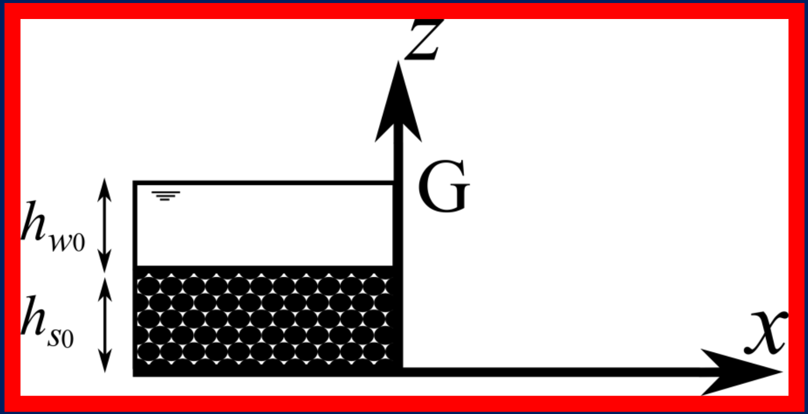

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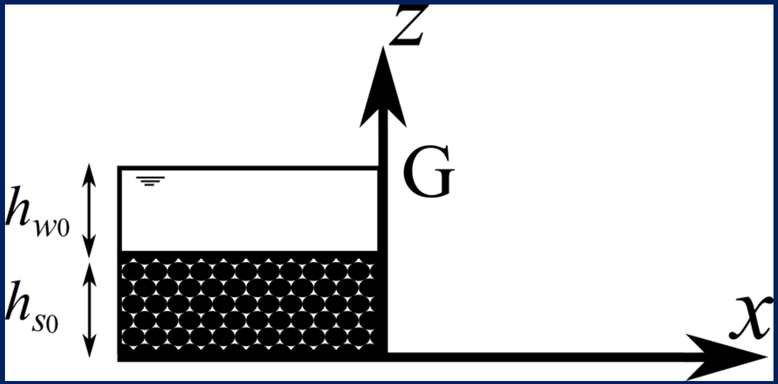
1.1 A Classification Hypothesis

- More general case
- Ratio h_{w0}/h_{s0} is important
- Quite complex case



Submerged

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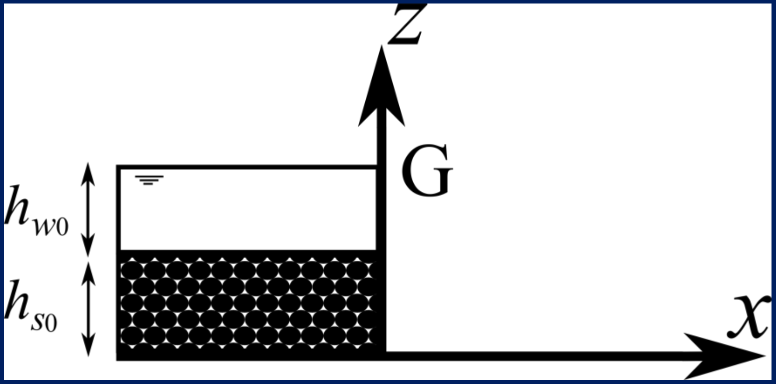

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1.3 Approaches to the Problem

1. Theoretical
2. Experimental
3. Numerical

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1. Theoretical **2. Experimental** 3. Numerical

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1. Theoretical **2. Experimental** 3. Numerical

Why:

Not necessarily the easiest one.

Not the hardest either.

Allows us to look directly at the physics of the problem.

1.3 Approaches to the Problem

1. Theoretical **2. Experimental** 3. Numerical

Physical Modelling Advantages

a) Difficult to measure this kind of flow in Nature.

b) Need to identify the ruling parameters.

c) Identify different phenomena.

d) Obtain a complete data base for numerical models validation.

1.3 Approaches to the Problem

1. Theoretical **2. Experimental** 3. Numerical

What to measure?

a) Wave celerity propagation.

b) Water height.

c) Sediment dispersion.

d) Velocity field for water and sediments.

2. Experimental Set-up

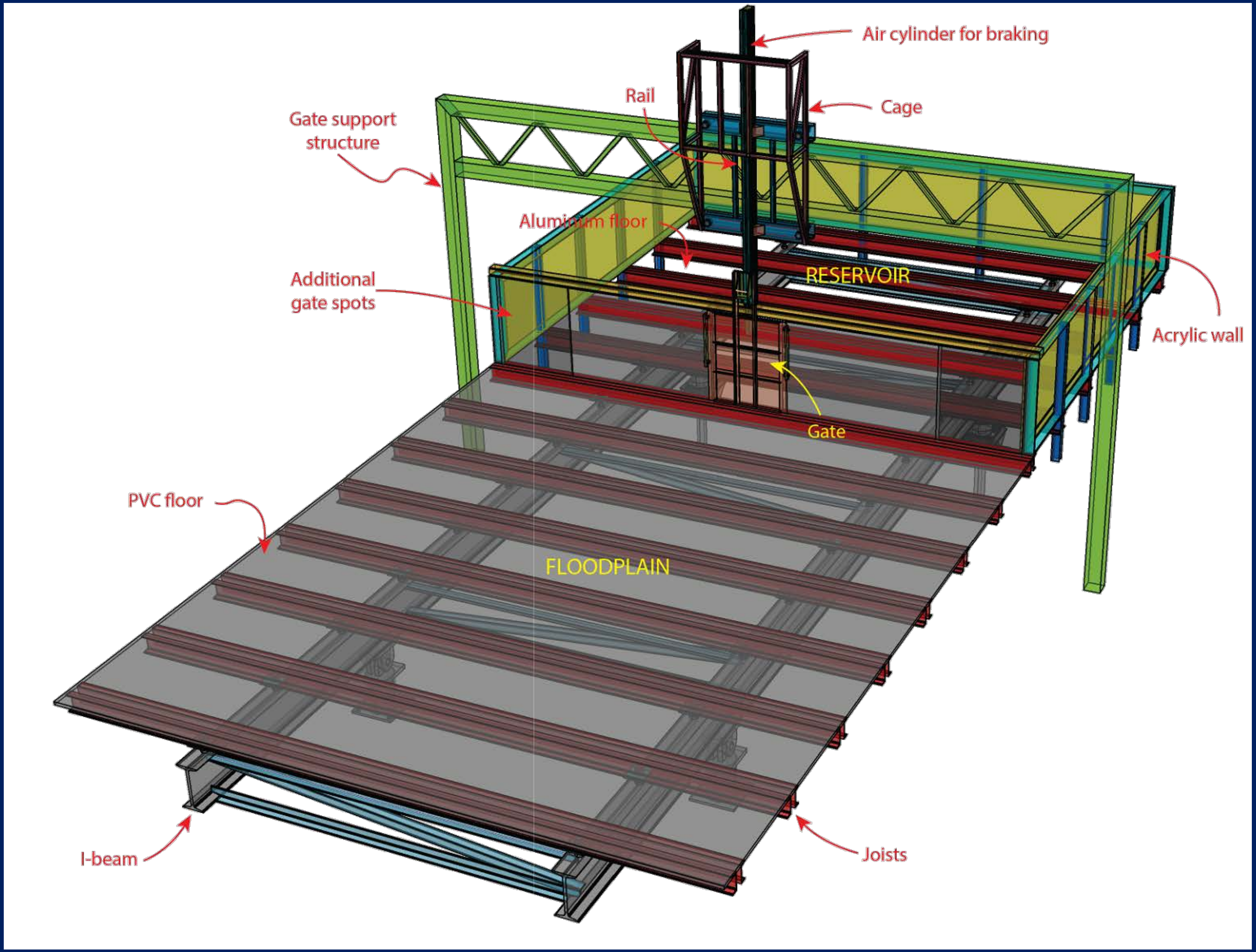
NCCHE Dam-break flume:

a) Located at the National Sedimentation Laboratory @ Oxford. MS. USA.

b) L = 7.6 m tilting platform; W = 3.66m; h = 0.61 m (reservoir glass side walls).

c) Dam-break modelled by an upward moving gate (v_g = 8 m/s)

2. Experimental Set-up



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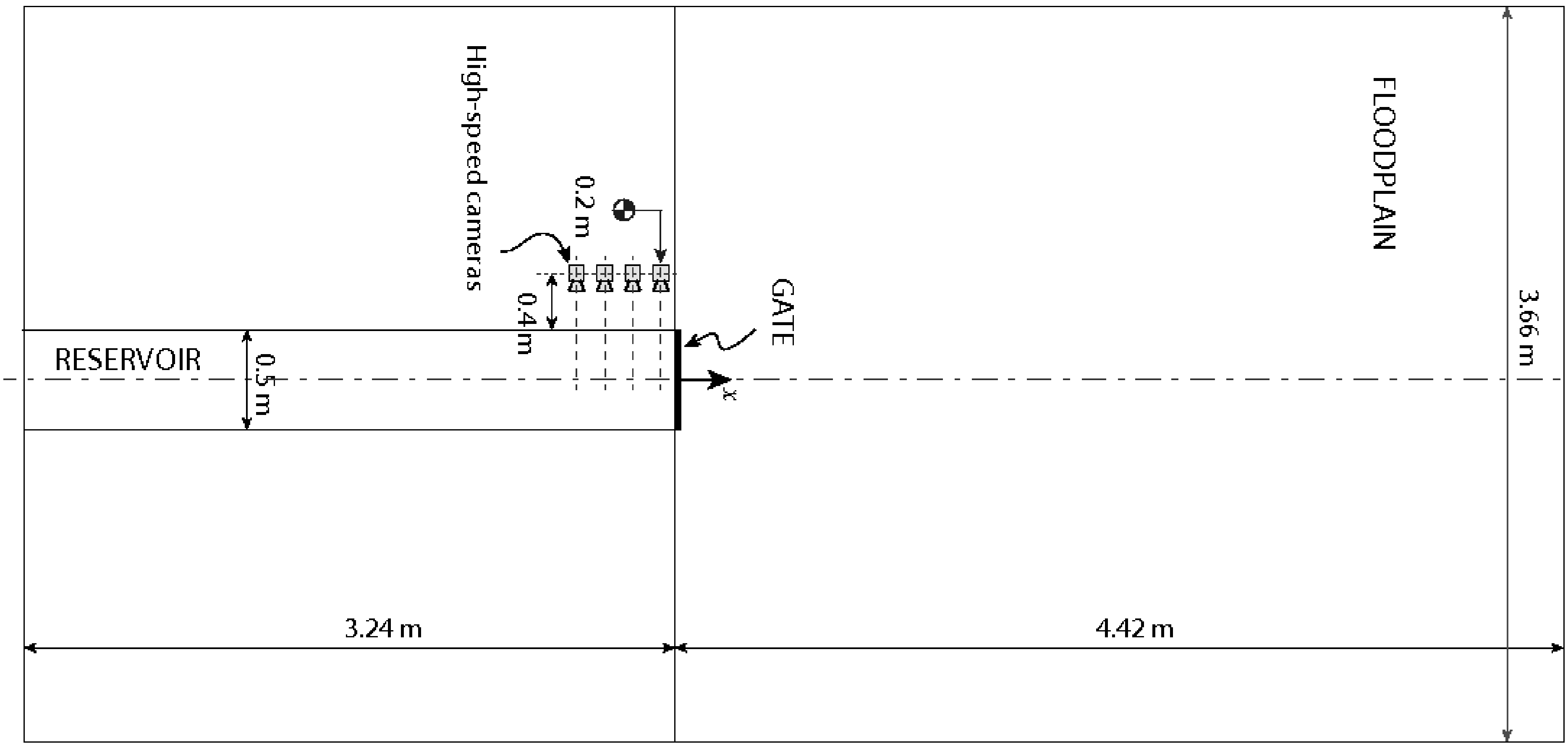
d) Upstream channel: 0.50 m wide, 0.50 m high and 3.24 m long.

2. Experimental Set-up



2. Experimental Set-up

Experimental Conditions:

a) h_{w0} = 0.40 m

b) h_{s0} = 0.20 m

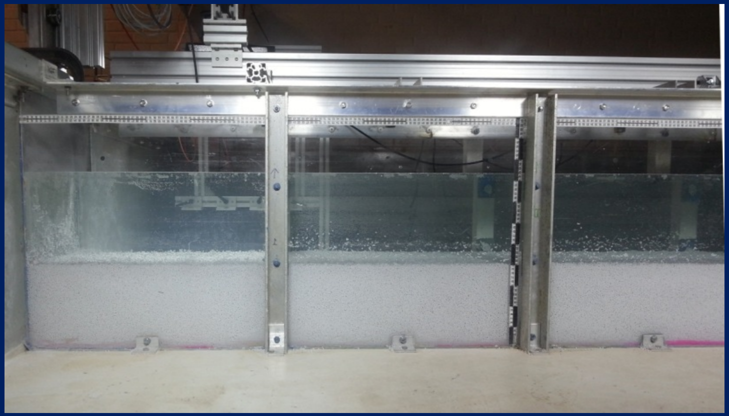
c) d_{50} = 2.87 mm

d) ρ_s = 1.42

e) Shape Factor = 0.83

f) Angle of repose = 30º

g) Packed bed

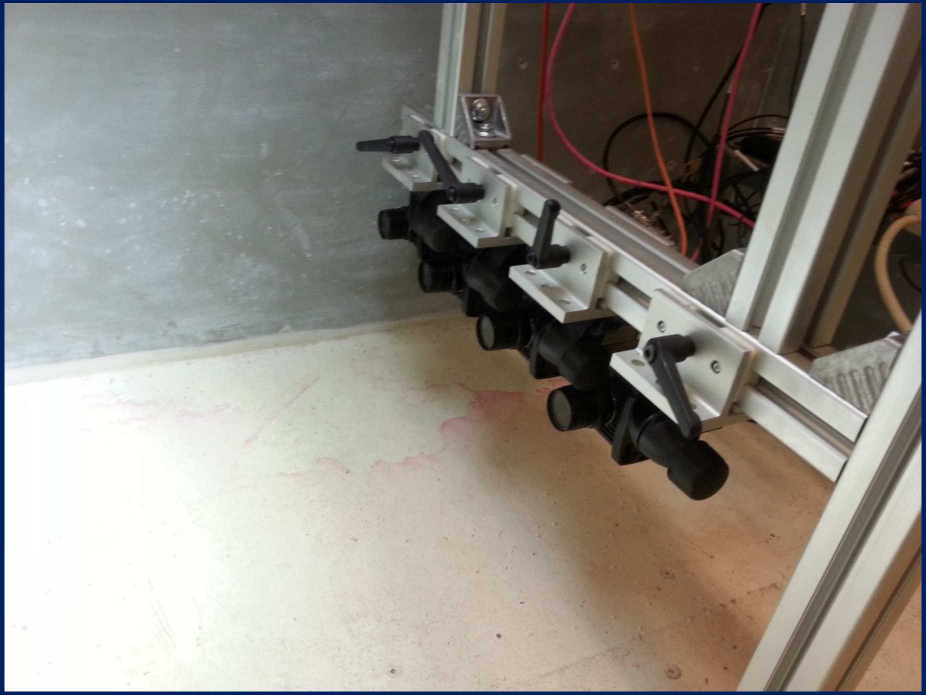


3. Instrumentation

a) **4 high speed cameras:**
   - 1.4Mpix
   - Up to 1000 kHz

b) Wide angle camera.

c) Acoustic Transducers.

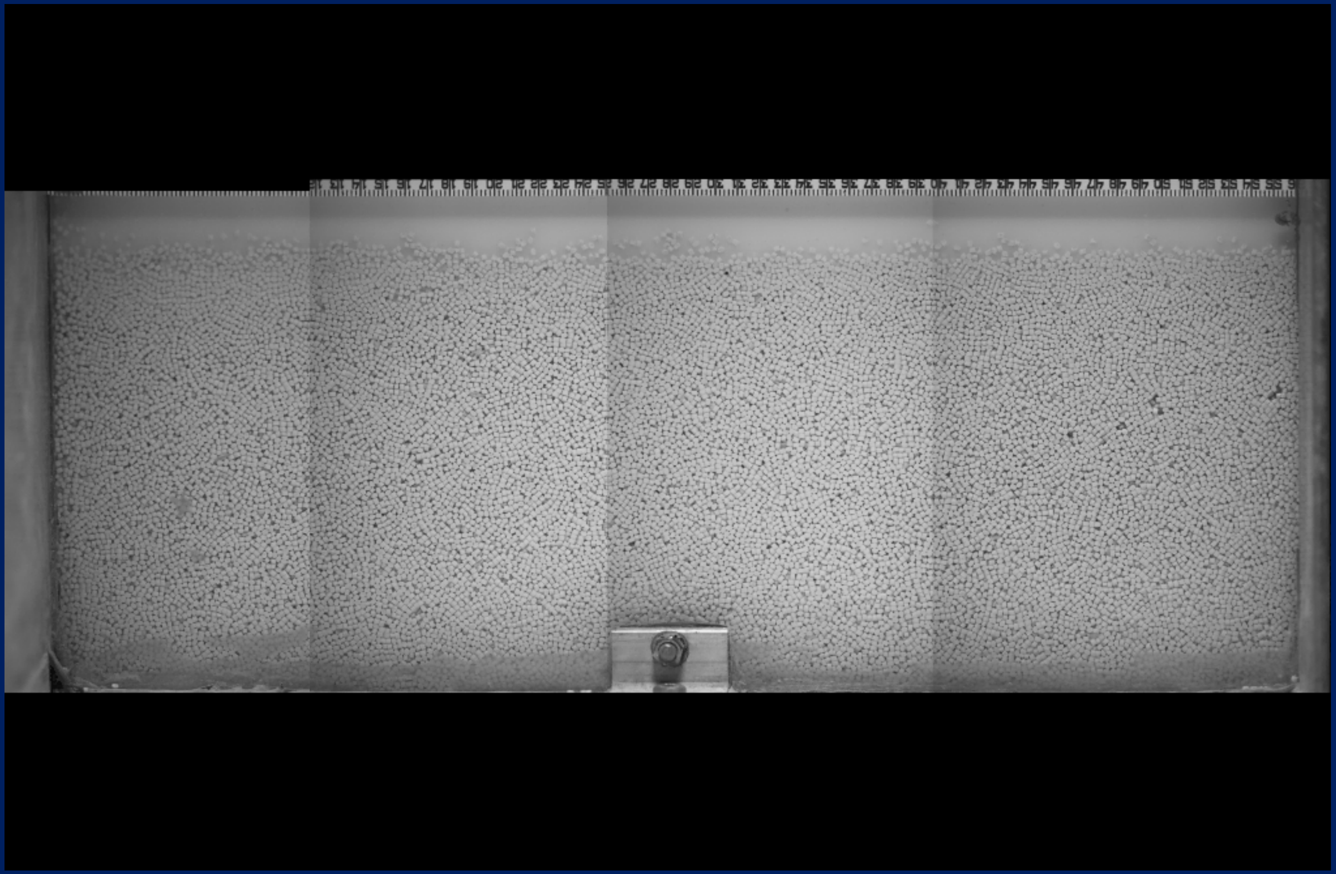


Q: What to do with fast cameras?
A : Photograph the flow and extract quantitative information.

4. Measurement Techniques

Flow Direction

4. Measurement Techniques



Flow Direction

4. Measurement Techniques

Velocity Field Measurements

1. Particle Tracking Velocimetry

2. Particle Image Velocimetry

4. 1 Particle Tracking Velocimetry

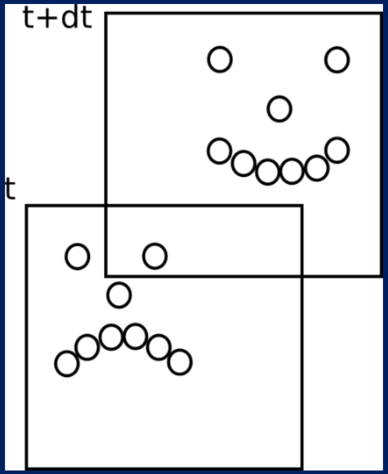
a) Detect particles in each image of a sequence.

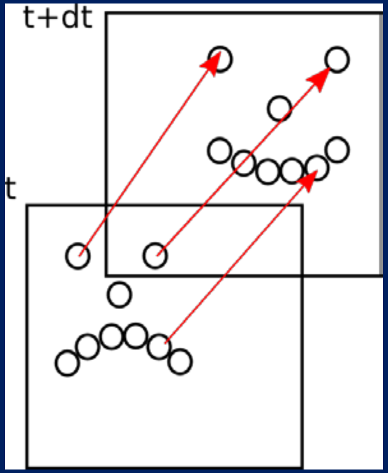
b) Particle tracking between consecutive images.

c) Displacement vector determination.

d) Lagrangian method.

e) Resolution up to particles' diameter (even less)!





4. 1 Particle Tracking Velocimetry

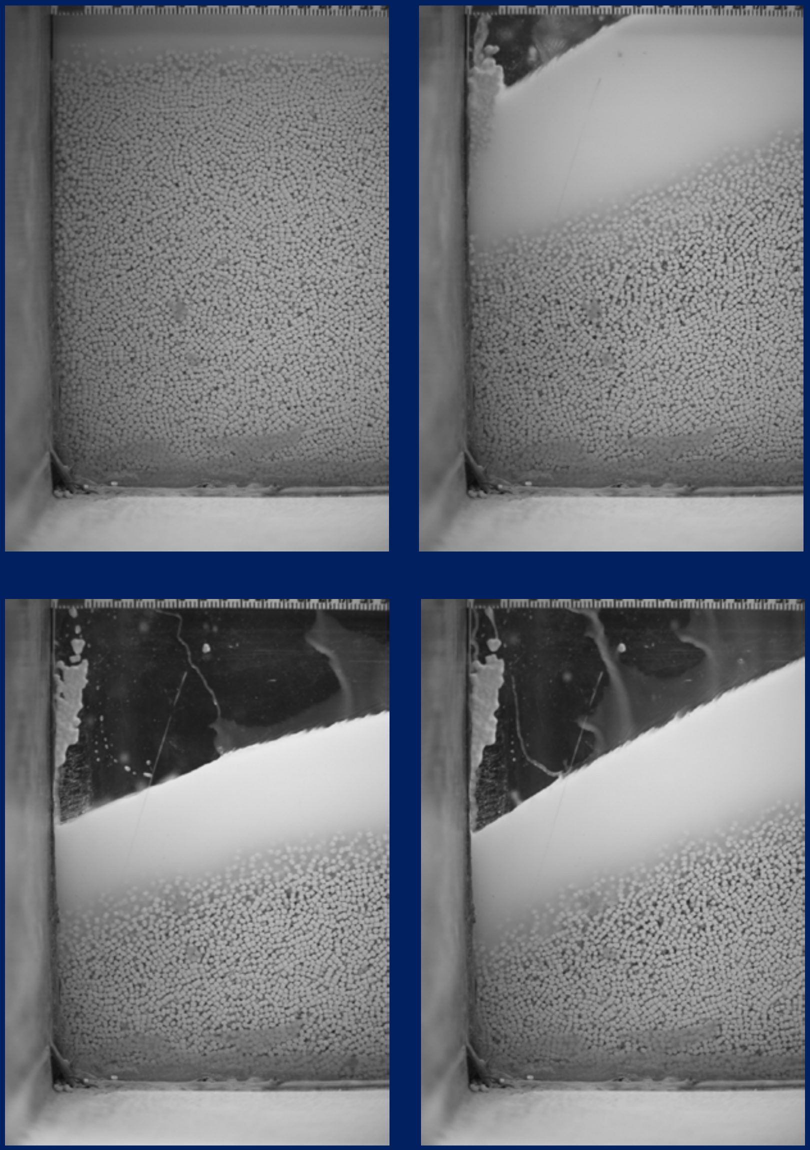
a) Track the final destination of the sediments.

b) High computational costs

4. 1 Particle Tracking Velocimetry

PTV Challenges.

- Wide range of velocity scales.
- Changing flow geometry.
- Difficult to track successfully all the time series.



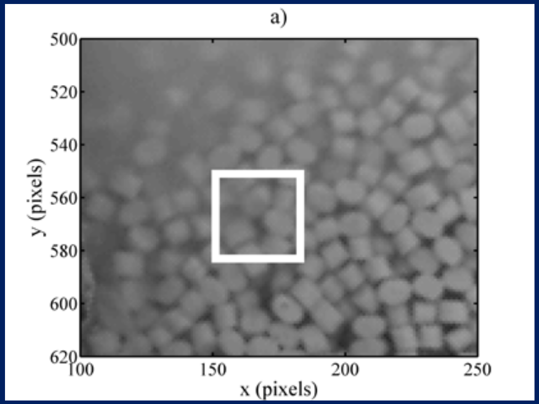
(Clockwise from top left: t = 0 s, 0.5 s, 1 s and 1.5 s

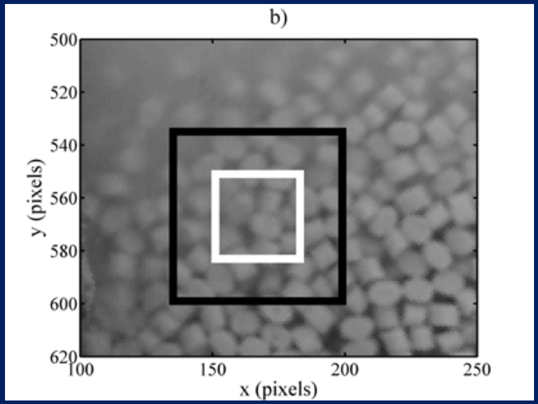
4.2 Particle Image Velocimetry

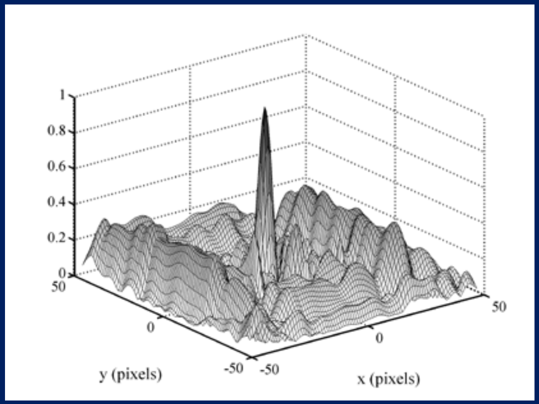
Follows the displacement of a pattern of particles.

Based on image cross-correlation.

Established and mature measurement technique. (e.g. Keane and Adrian (1992); Raffel et al. (2007)).







4.2 Particle Image Velocimetry

- More robust than PTV.
- Less computational demanding than PTV.
- Resolution of the interrogation window…
- No Lagrangian tracking.
- **Well suited to handle the different velocity scales**.

4. Measurement Techniques

Velocity Field Measurements

1. Particle Tracking Velocimetry

2. Particle Image Velocimetry

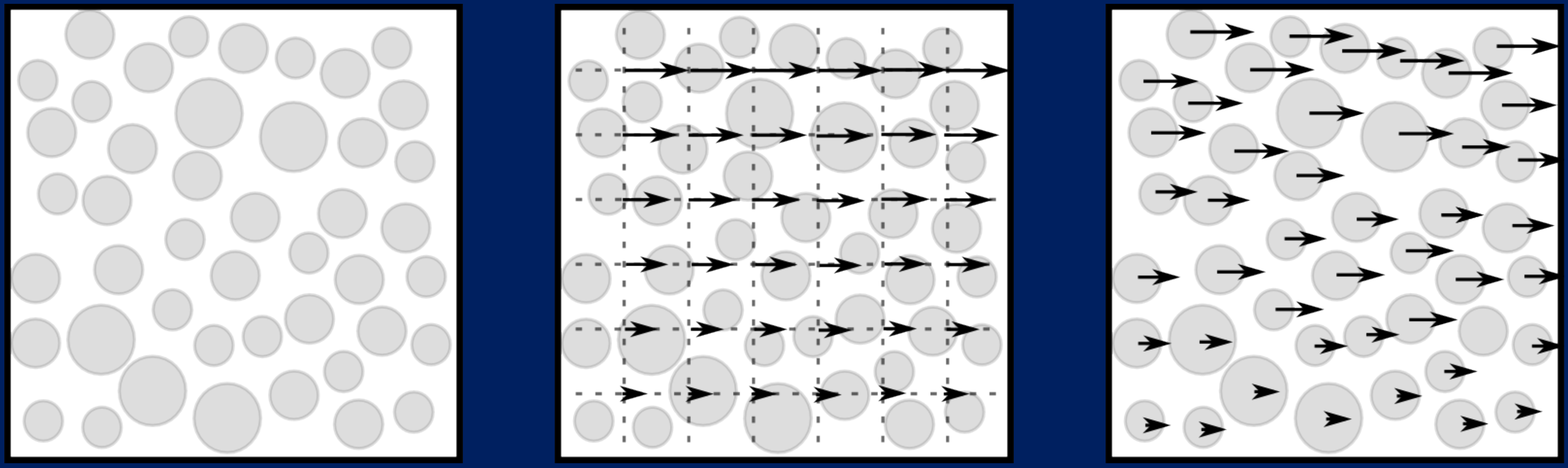
3. **Particle Image Velocimetry + Particle Tracking**

4.2 Particle Image Velocimetry

Robert Doisneau's "*Un regard oblique*"

4.3 Particle Image Velocimetry + Particle Tracking Velocimetry

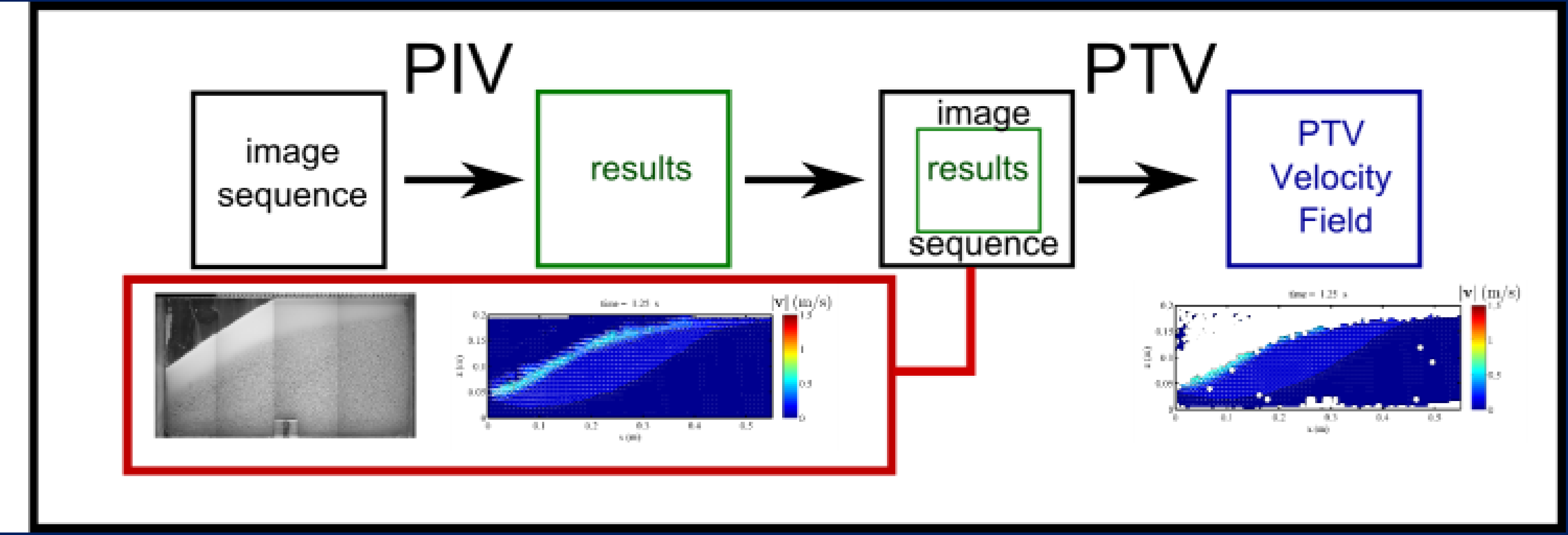
Proposed by Stitou and Riethmuller (2001) in order to extend PIV spatial resolution.



Particles | **PIV superimposed to particles** | **Interpolated velocity field for each particle**

4.3 Particle Image Velocimetry + Particle Tracking Velocimetry

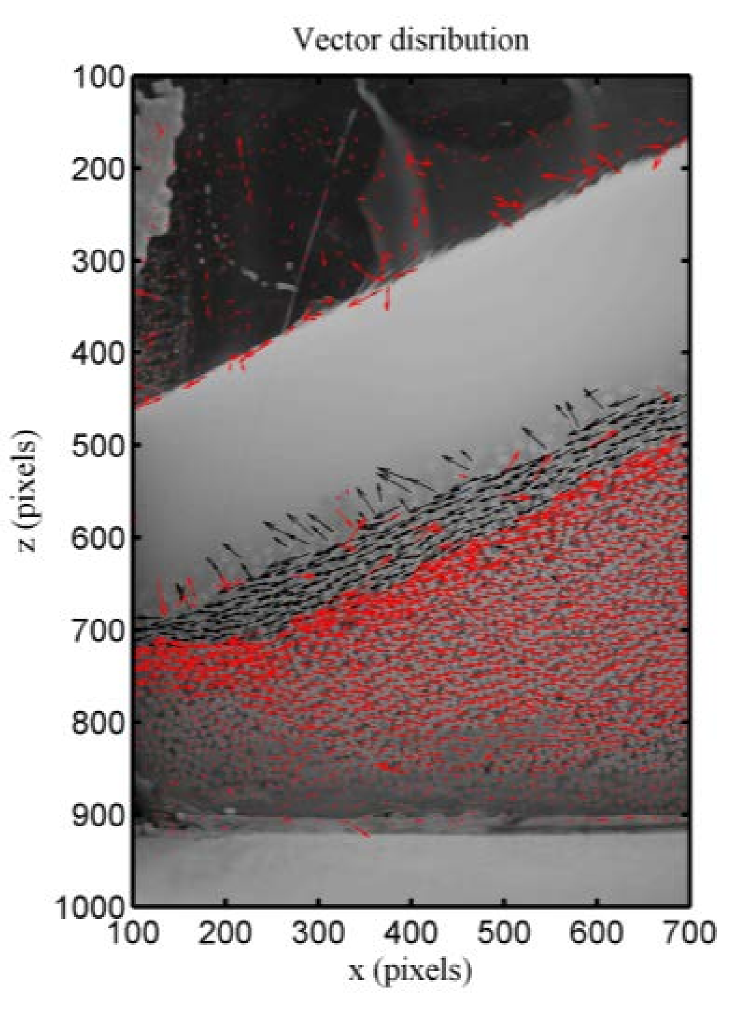
- PIV Algorithm: MatPIV v1.6 (Sveen, 2004)
- PTV Algorithm: Voronoi Tracking (Capart et al. 2002)



(Aleixo et al. 2014a)

4.3 Particle Image Velocimetry + Particle Tracking Velocimetry

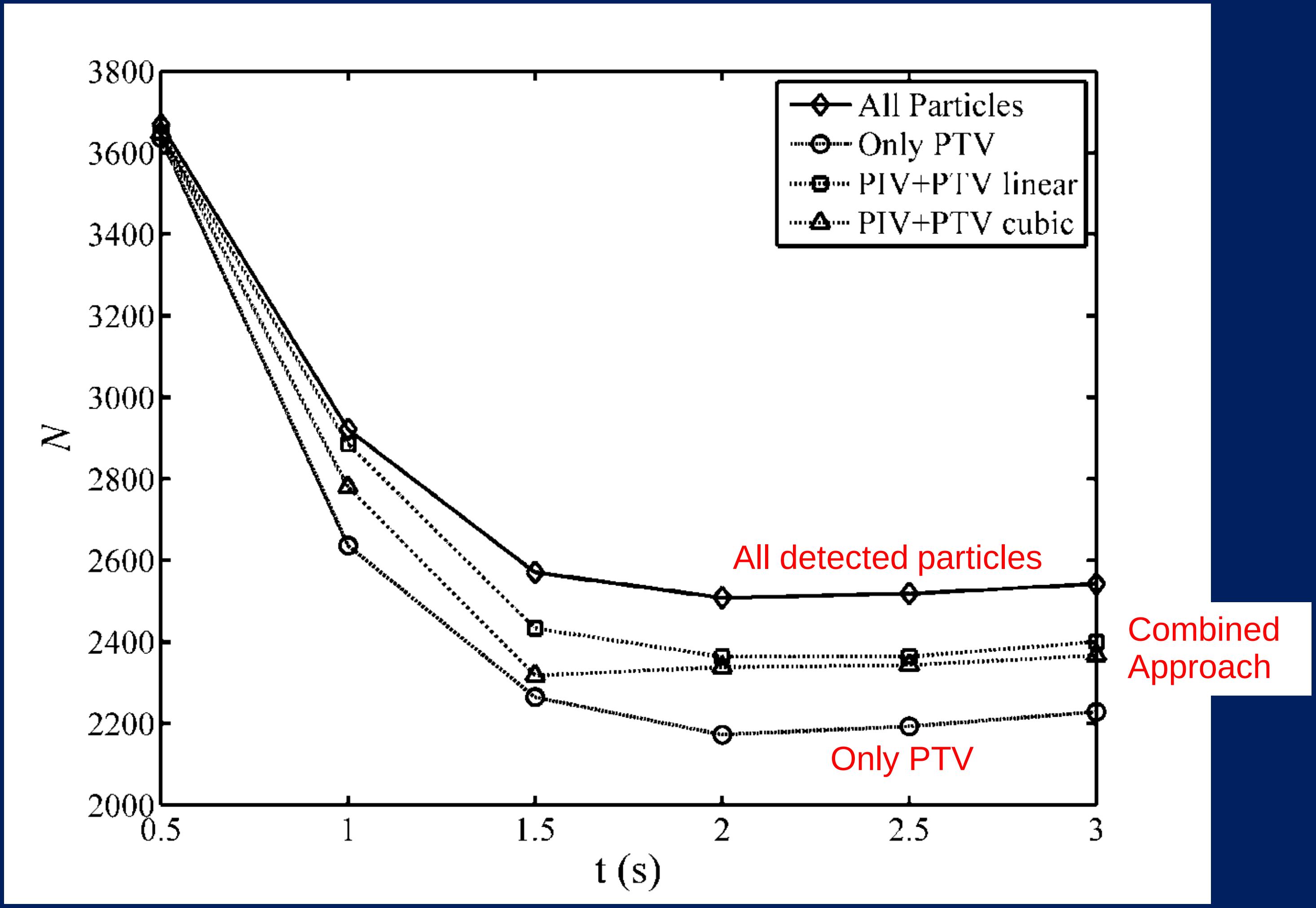
- More detected particles
- More realistic velocity field
- Different scales resolved.



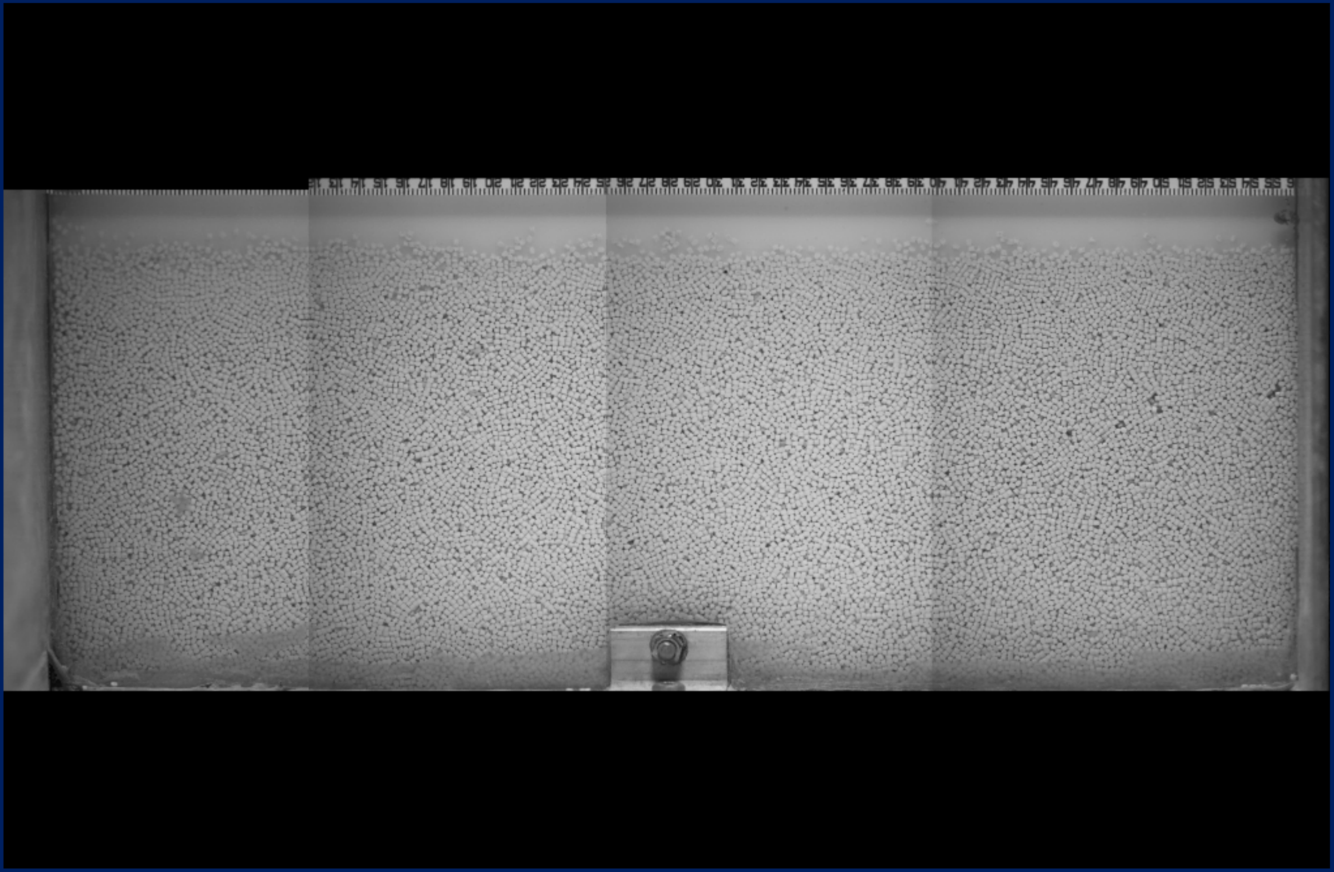
Red vectors: only PTV
Black vectors: PIV+PTV

4.3 Particle Image Velocimetry + Particle Tracking Velocimetry

Number of particles tracked



5. Results



Flow Direction

5. Results

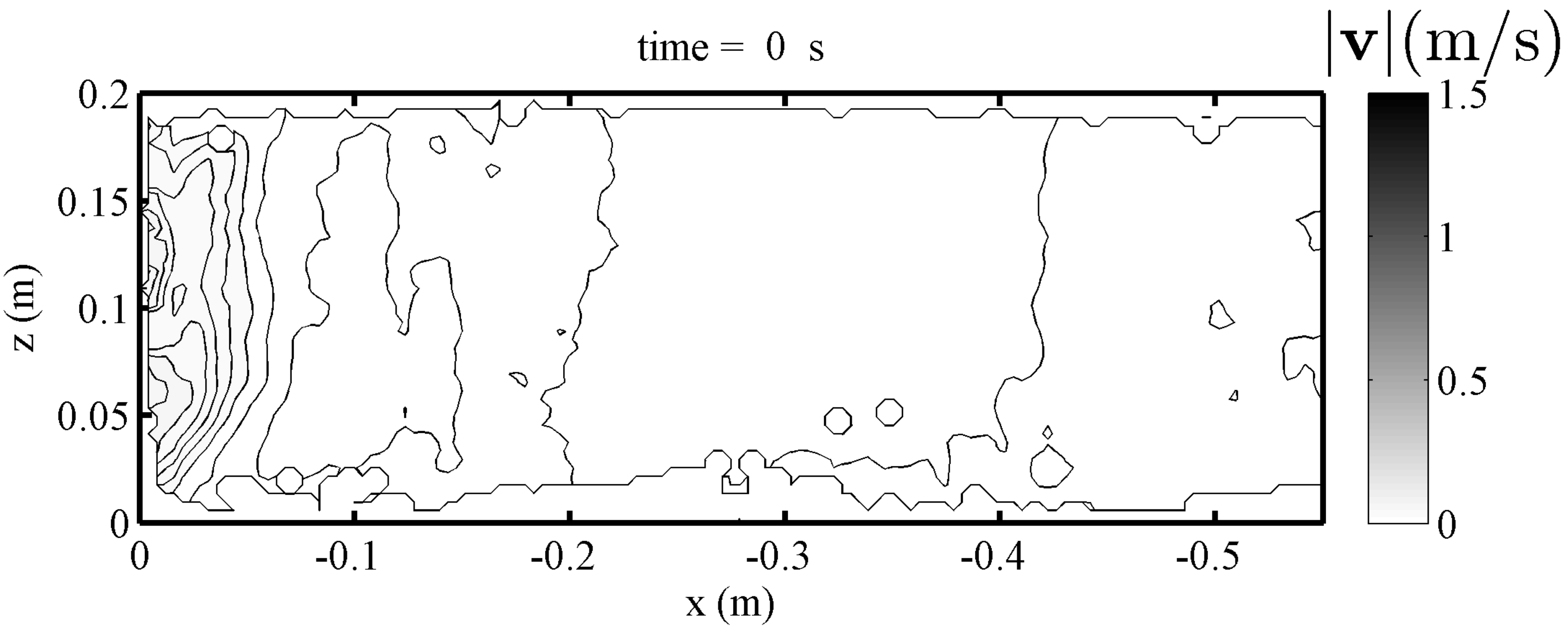
Different types of flow

- Sheet flow (uppermost sediment layer).
- Mass failure + plug flow.
- Plug collapse

- Sheet flow
- Mass failure + plug flow
- Etc.

5. Results

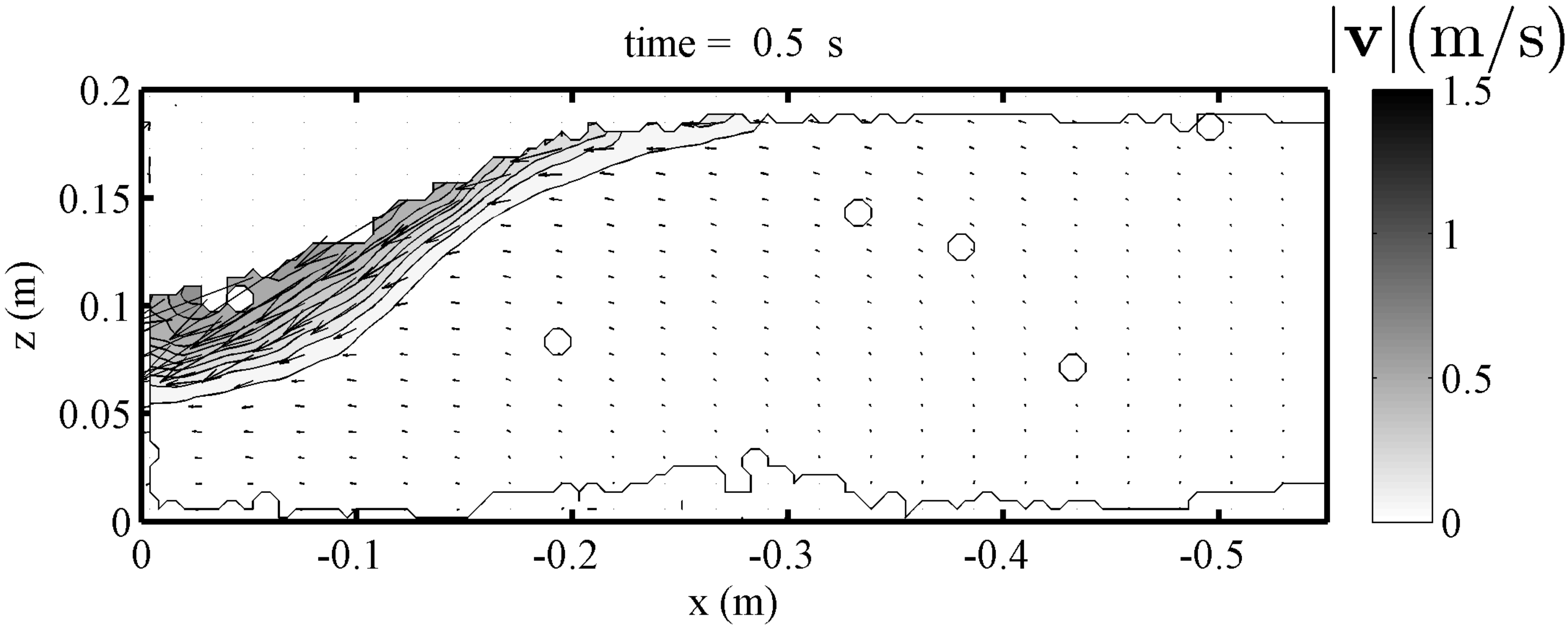
t < 1.08 s



(Aleixo et al. 2014b)

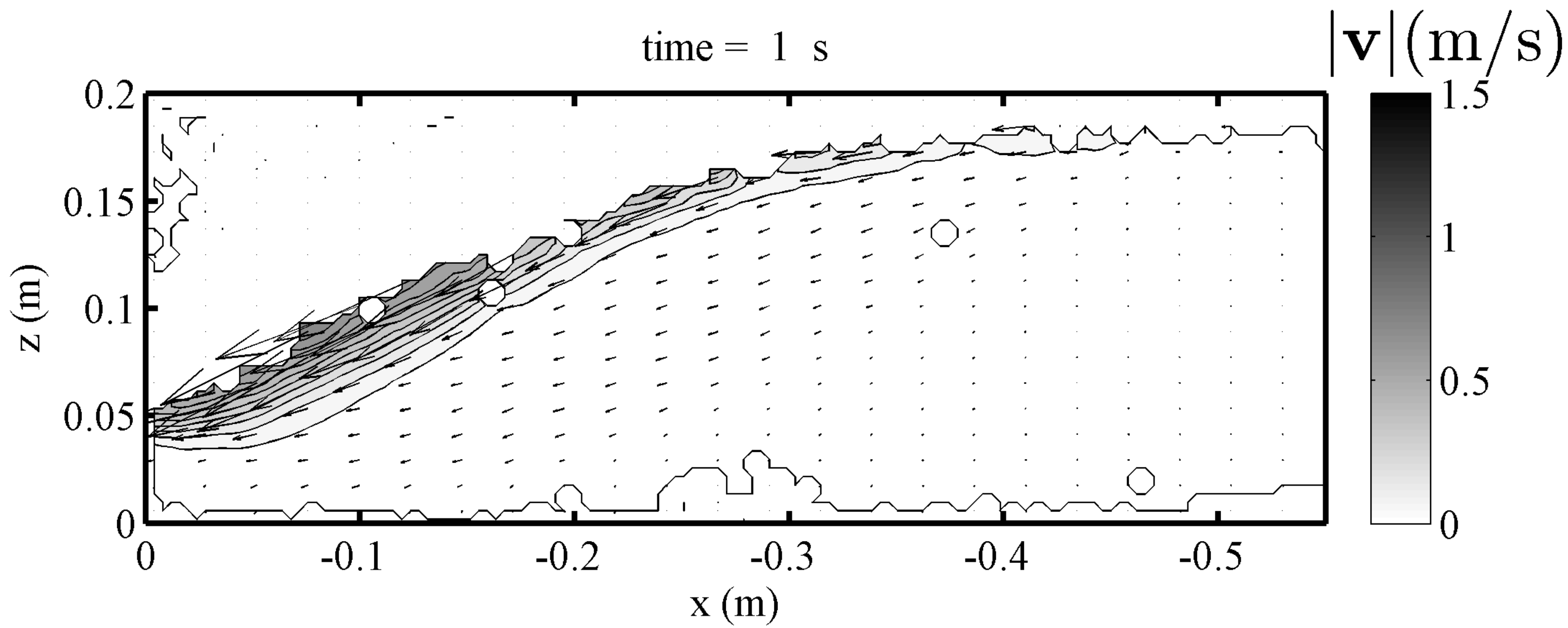
5. Results

t < 1.08 s



5. Results

t < 1.08 s

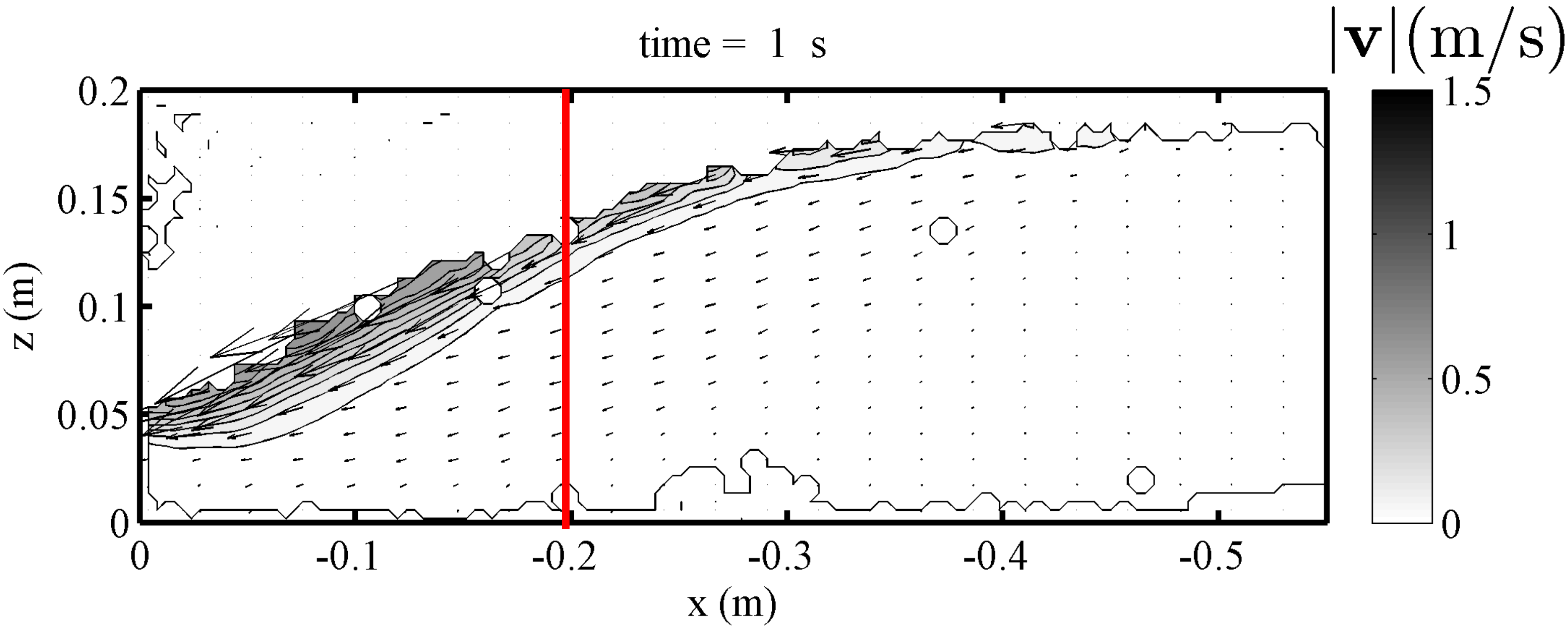


5. Results

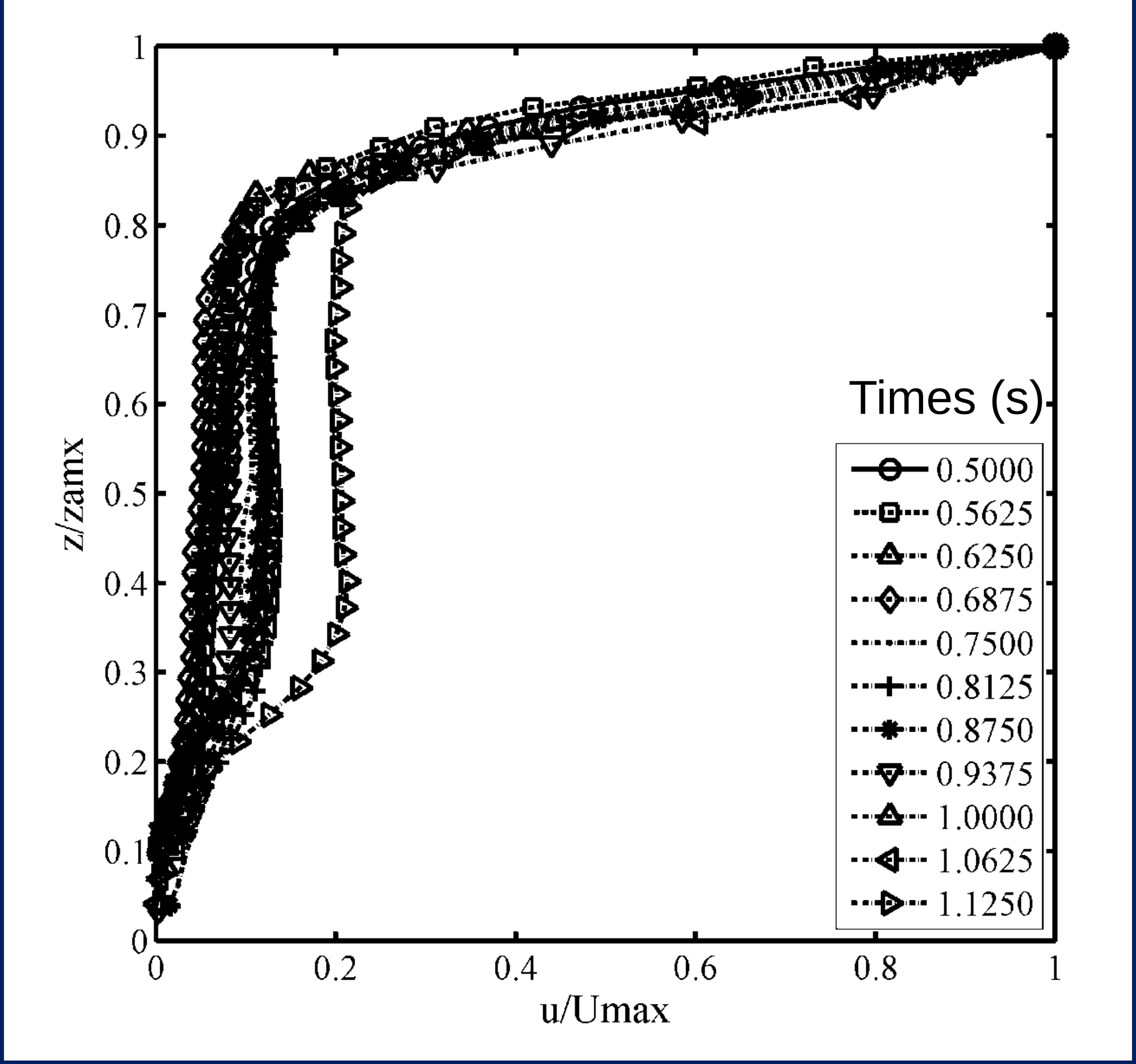
Velocity profiles analysis with time

Fixed section *x* = -0.1991 m;

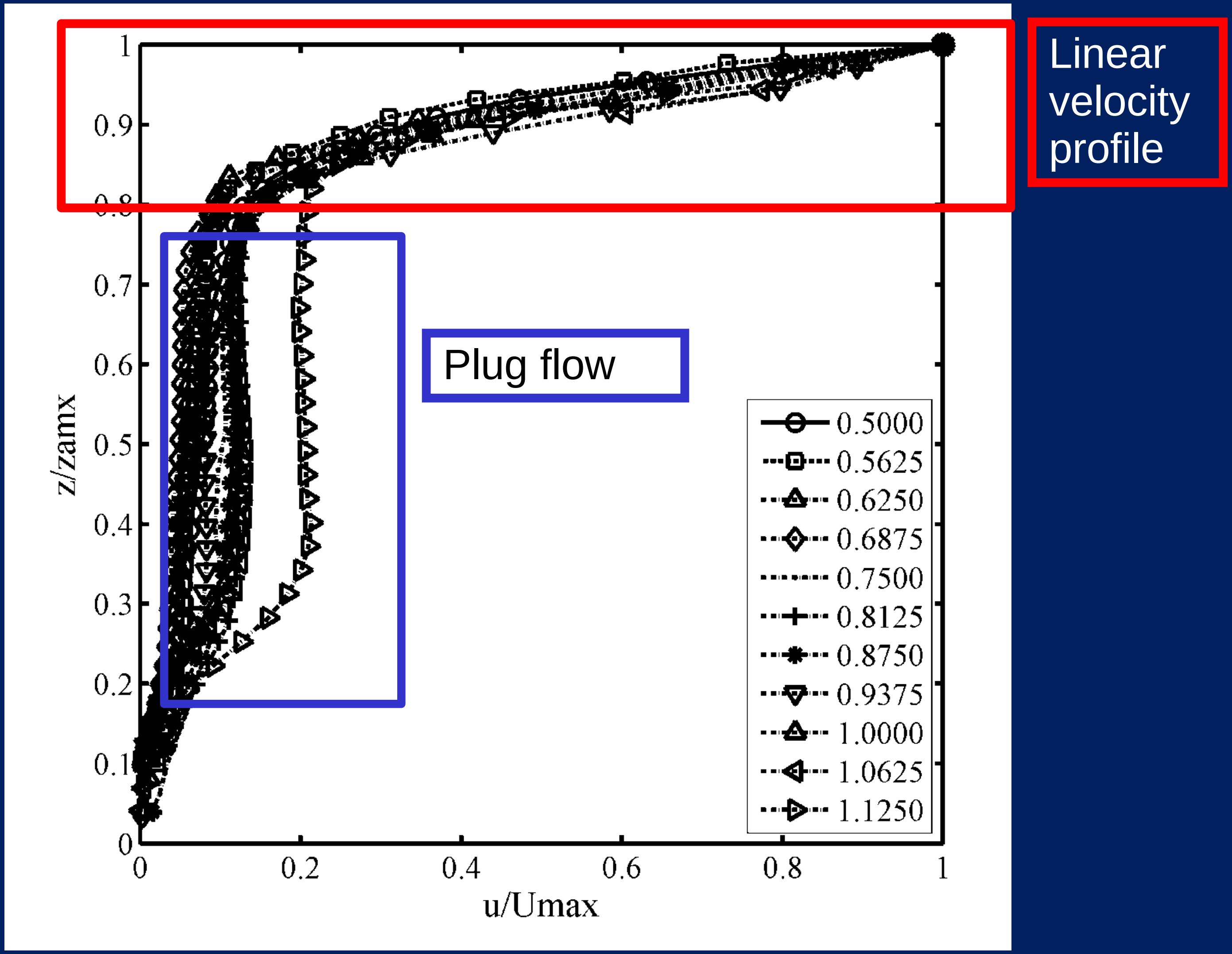
Velocity and length scale: (U_{max}, z_{max})



5. Results


Times (s)
0.5000
0.5625
0.6250
0.6875
0.7500
0.8125
0.8750
0.9375
1.0000
1.0625
1.1250
z/zamx
u/Umax
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

5.2 Detailed Analysis



5.2 Detailed Analysis

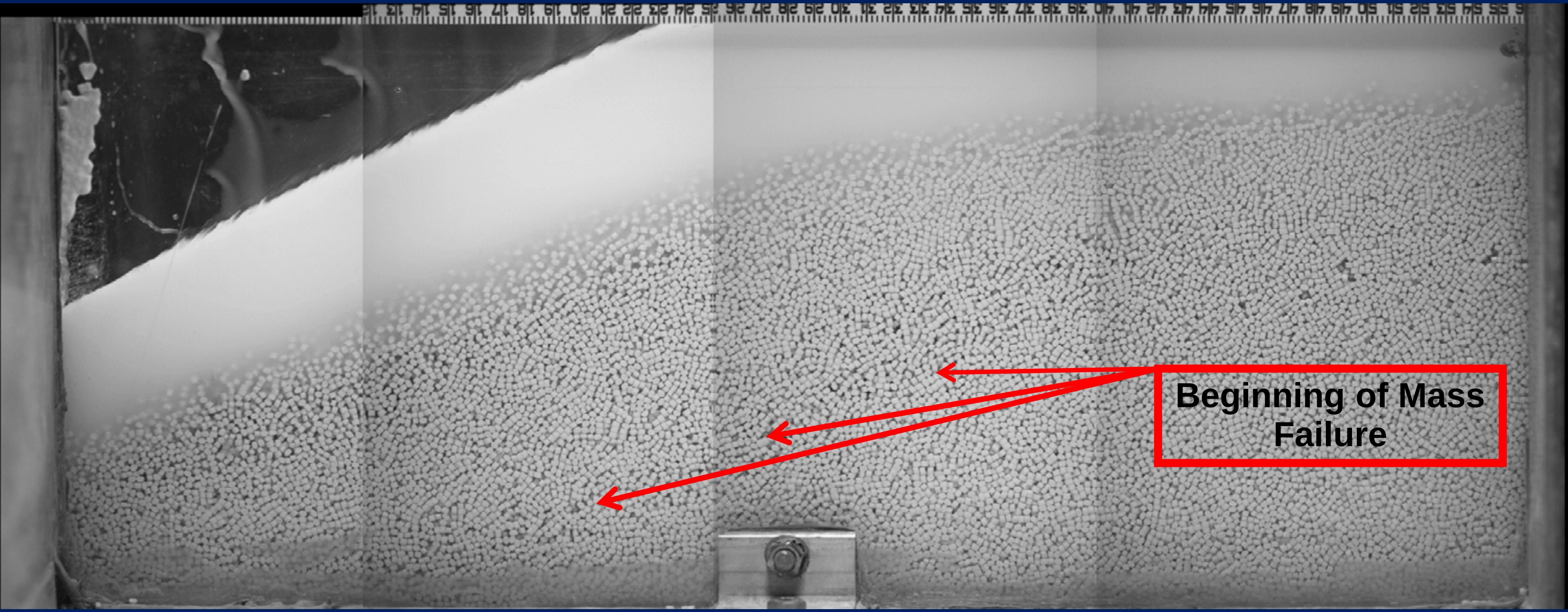
Mass failure + plug flow

t = 1.08 s

5.2 Detailed Analysis

Mass failure analysis

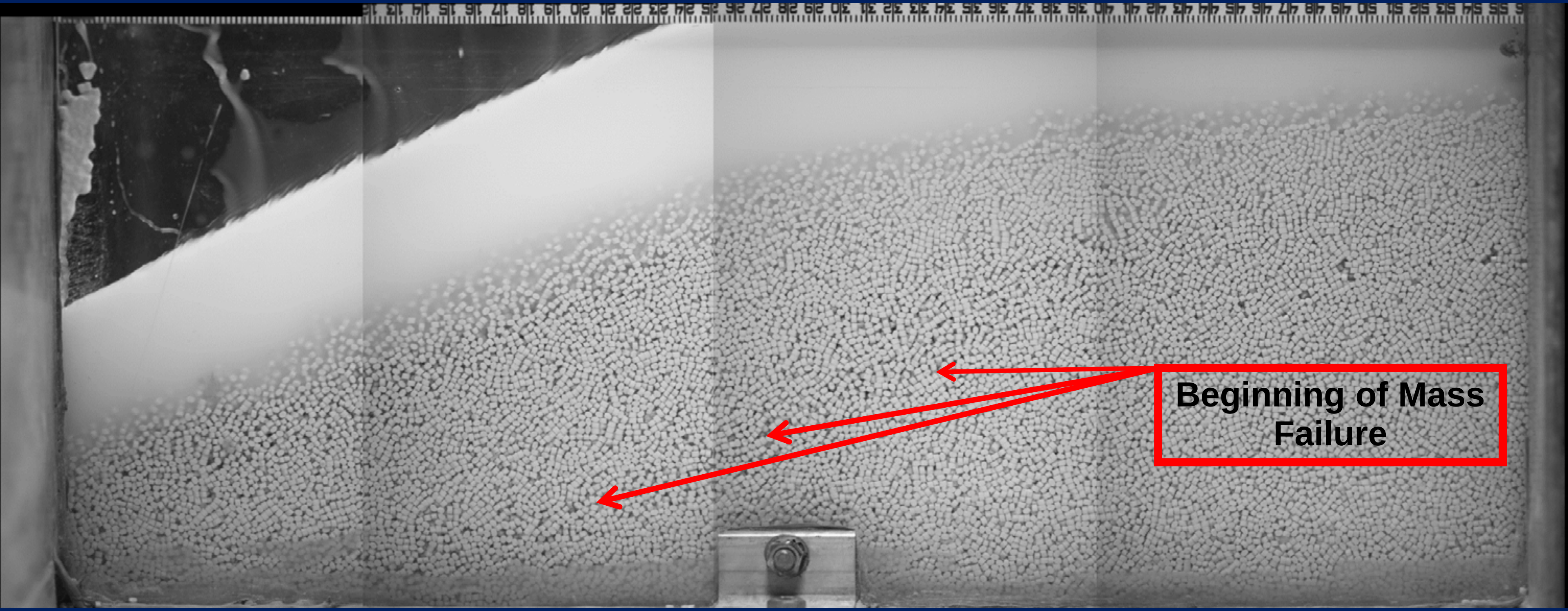
t = 1.08 s



5.2 Detailed Analysis

Mass failure analysis

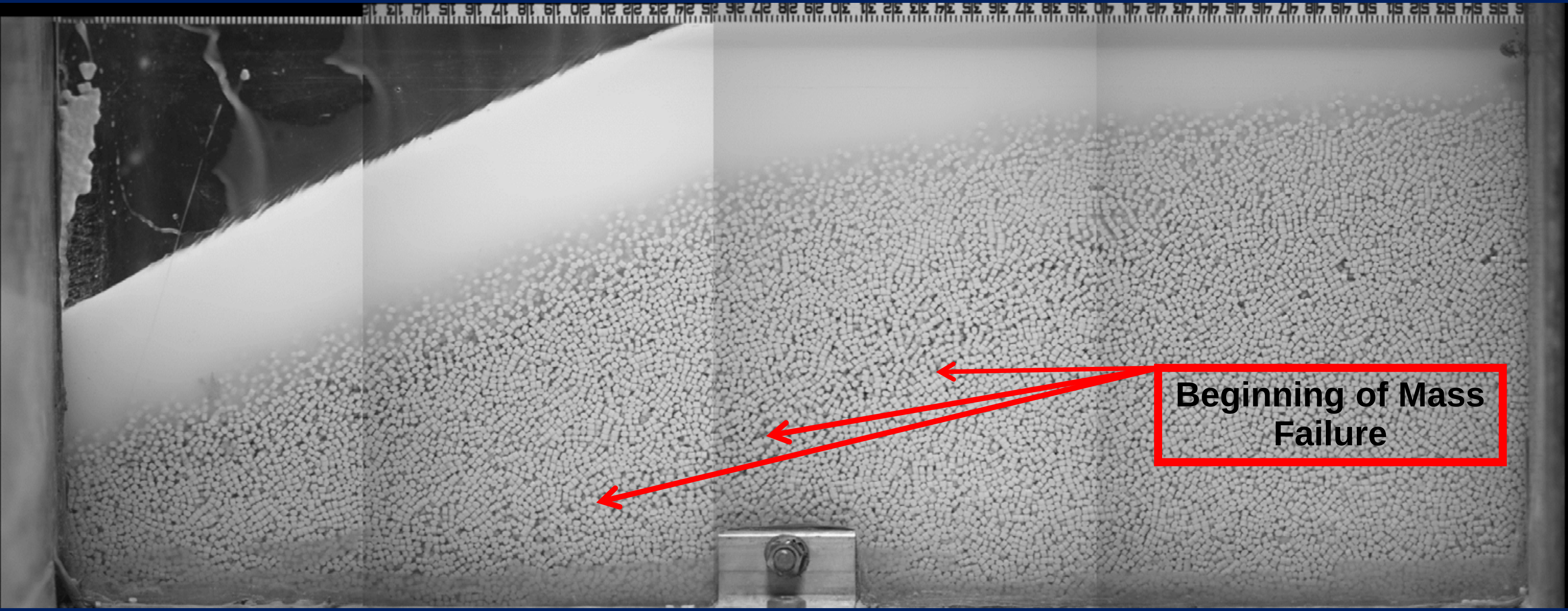
t = 1.1025 s



5.2 Detailed Analysis

Mass failure analysis

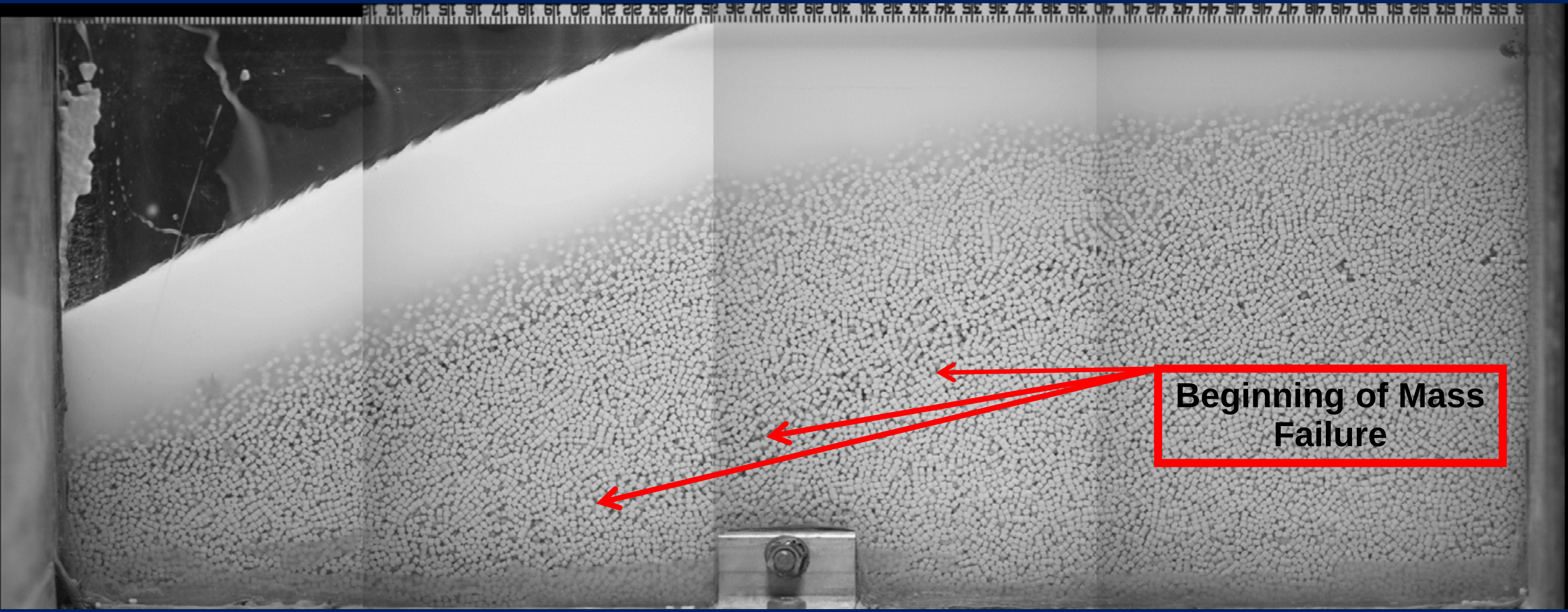
t = 1.125 s



5.2 Detailed Analysis

Mass failure analysis

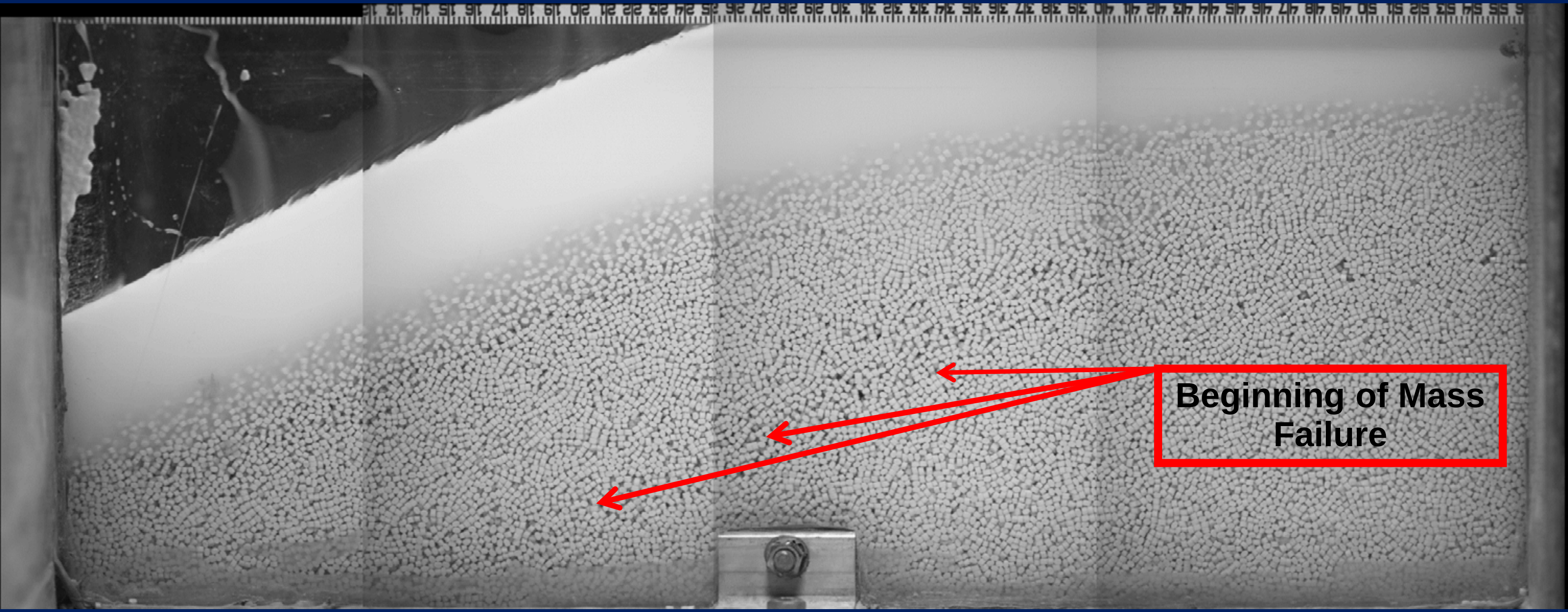
t = 1.1475 s



5.2 Detailed Analysis

Mass failure analysis

t = 1.17 s



5.2 Detailed Analysis

How to identify the mass failure?

a) Sediments moving under the fluid solicitation

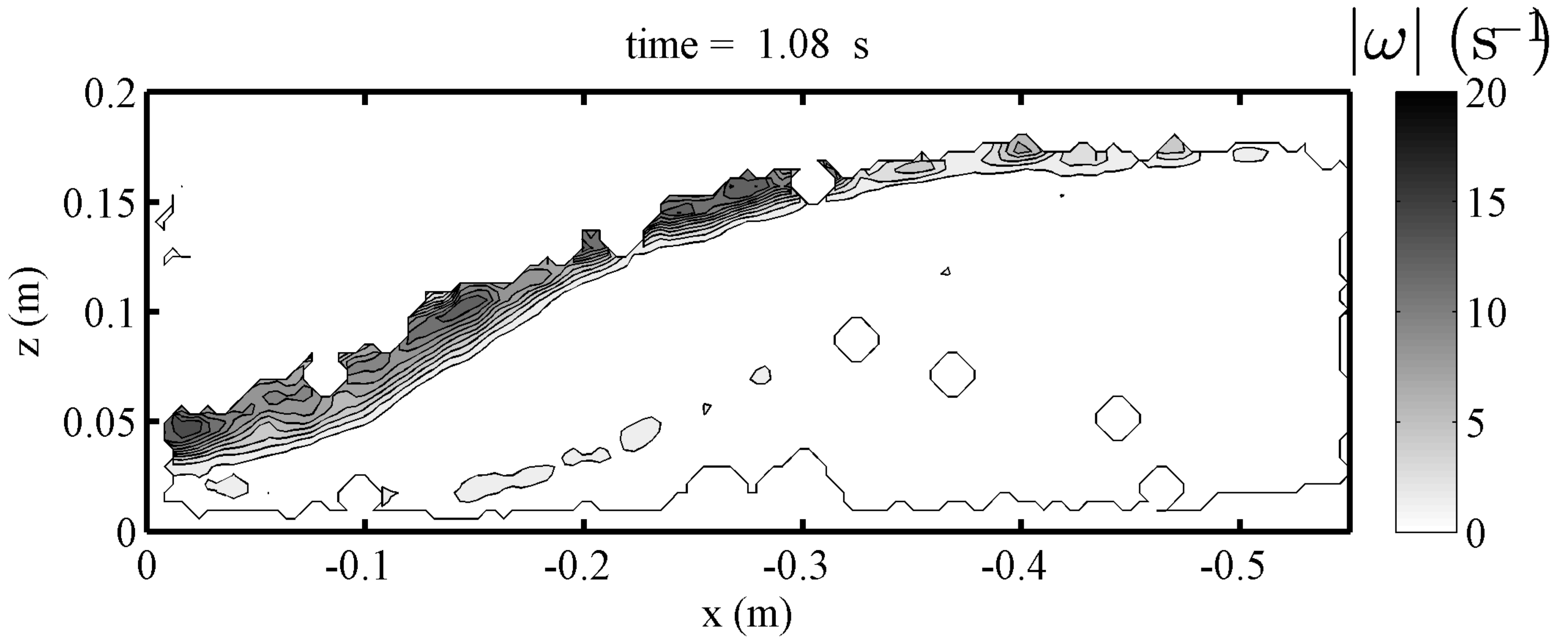
b) Shear stress important: $\partial u / \partial z$

Extracted from the vorticity of the flow

$$\vec{\omega} = \nabla \times \vec{v}$$

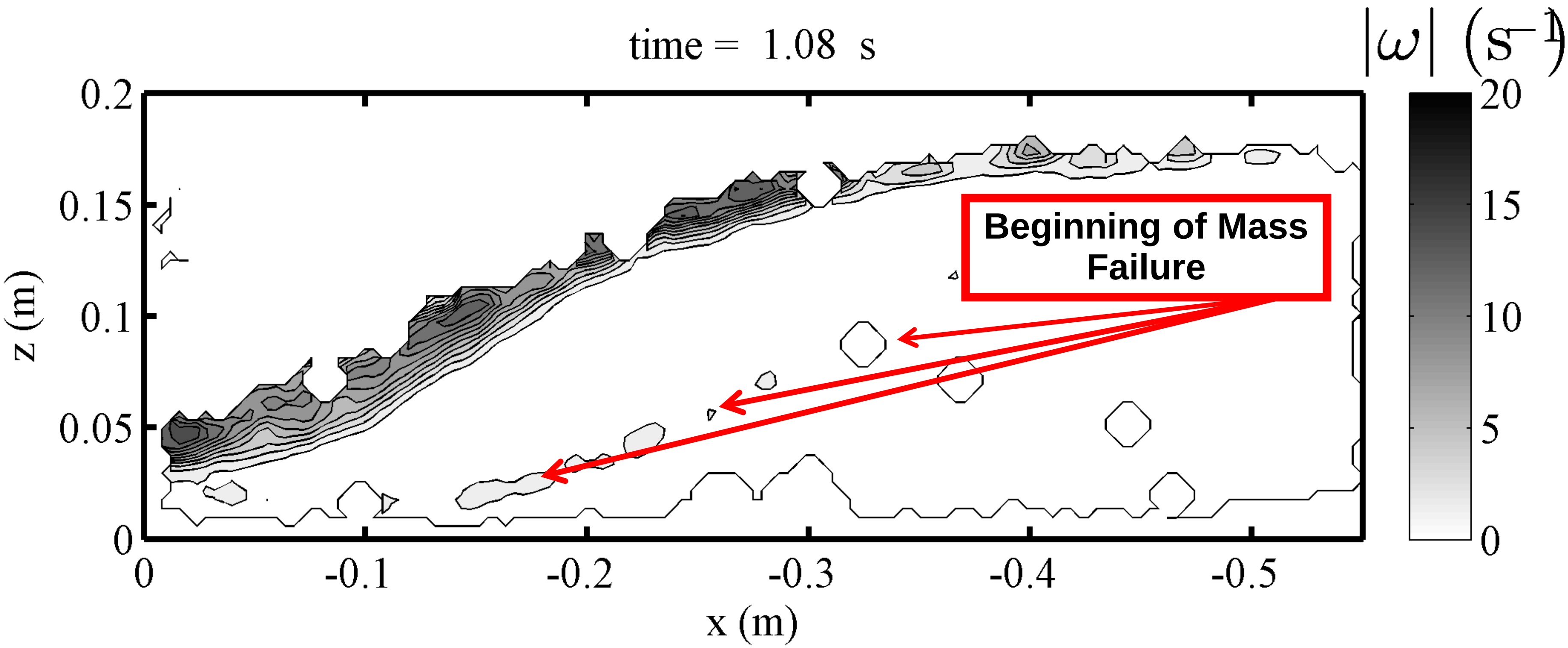
5. Results

Mass failure analysis



5.2 Detailed Analysis

Mass failure analysis



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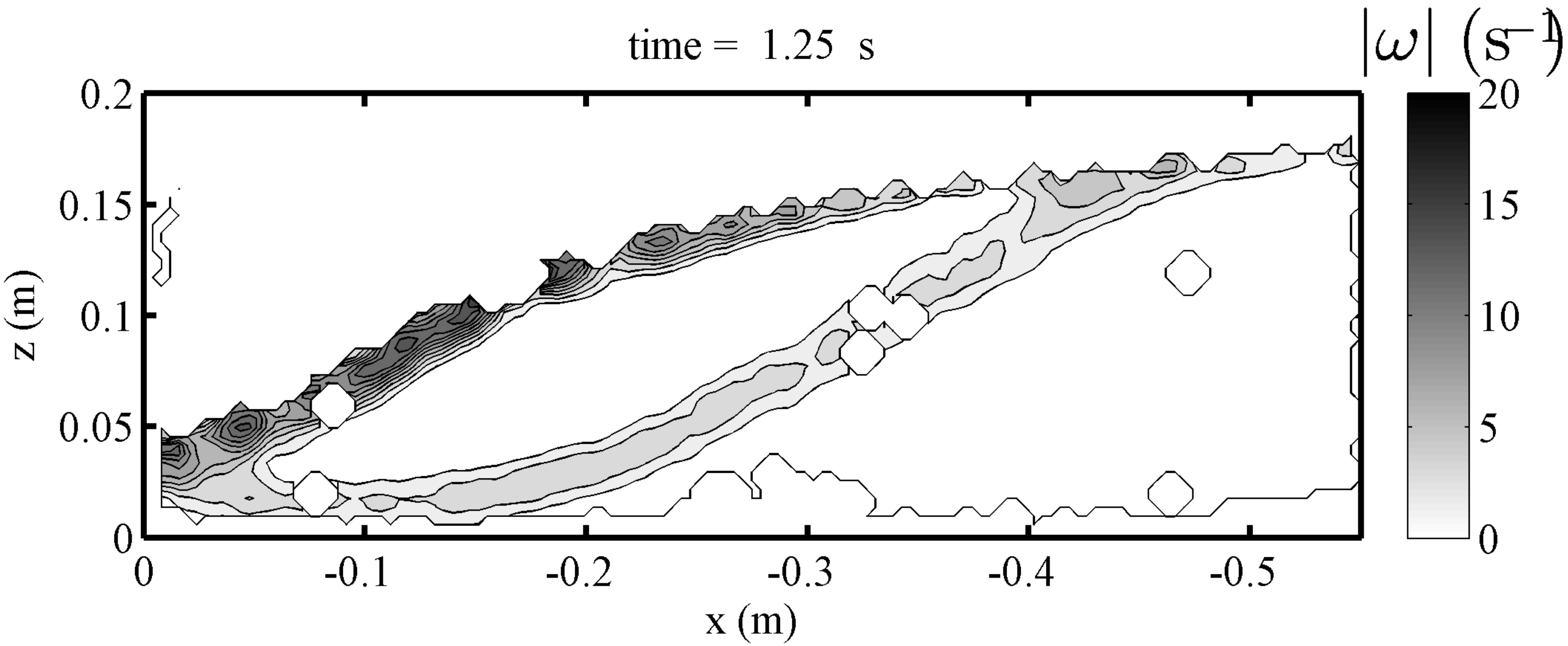
Mass failure analysis



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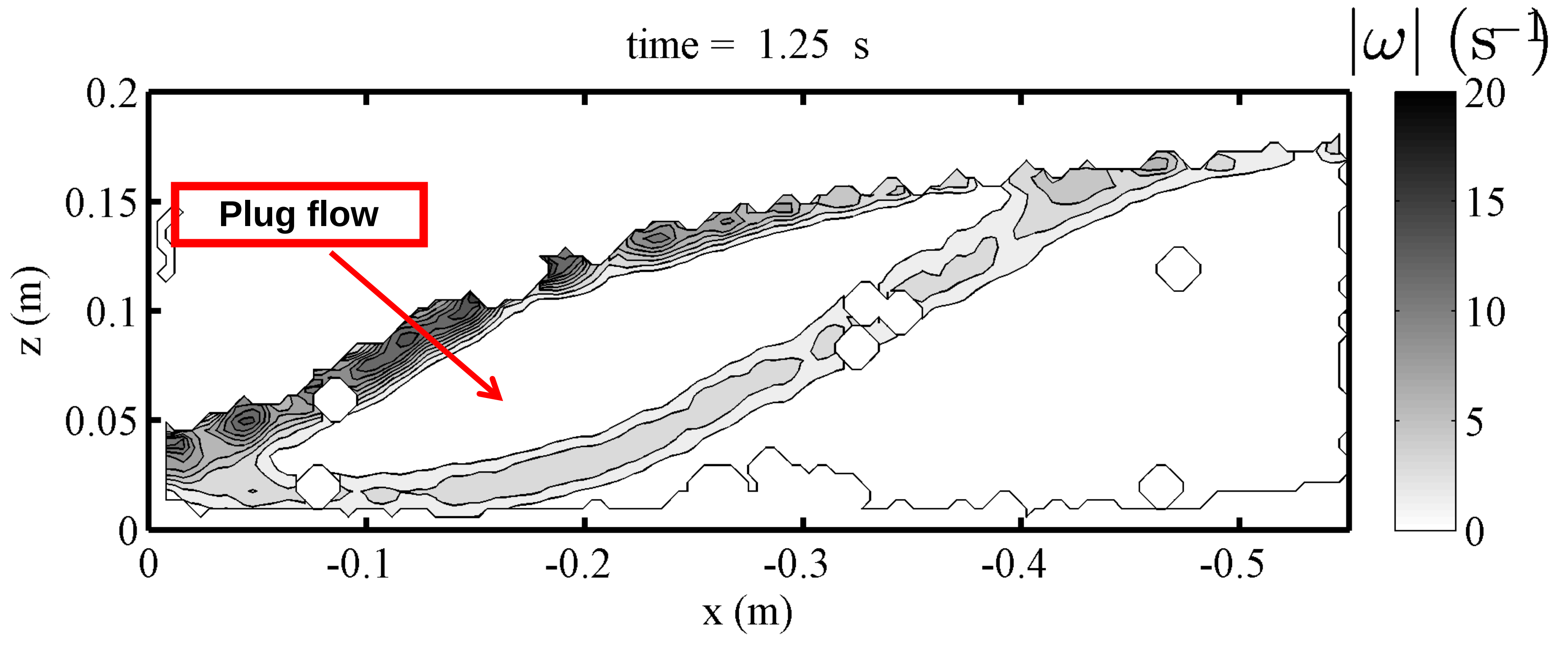
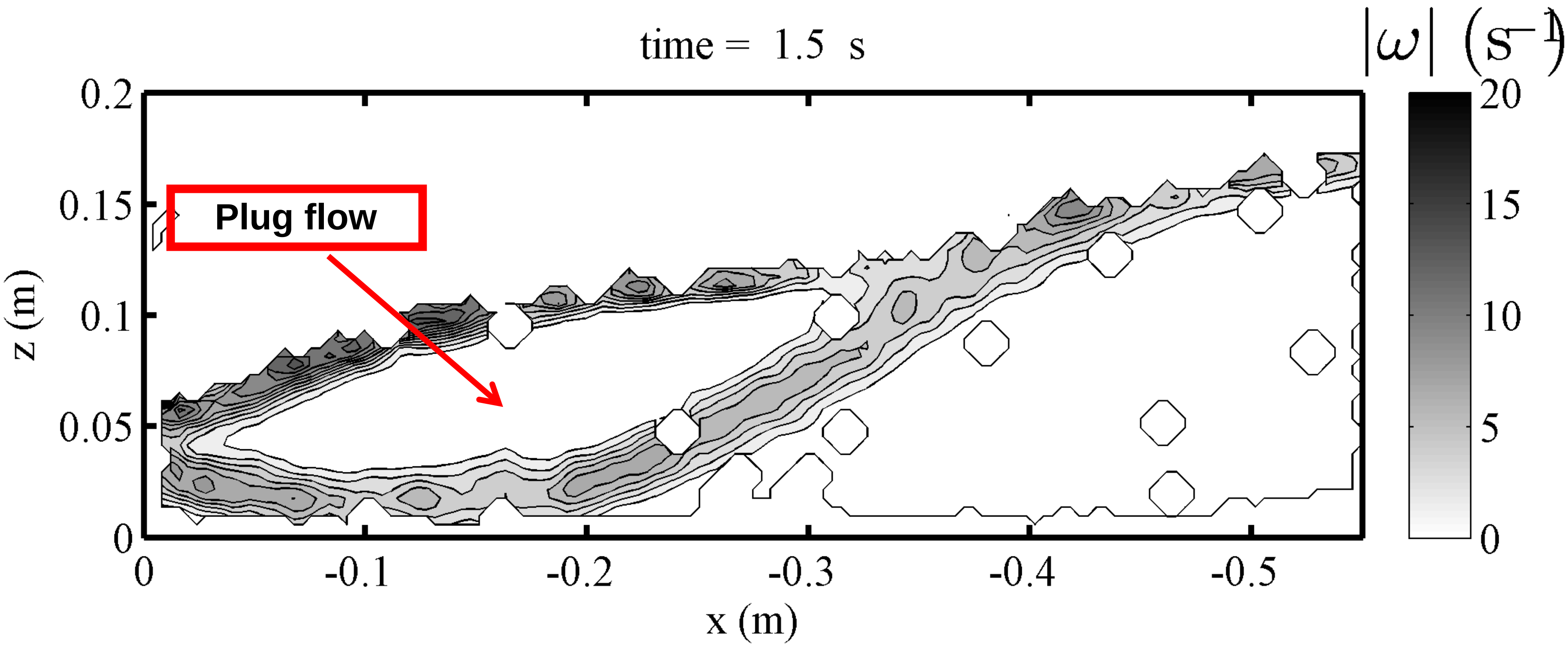
Mass failure analysis



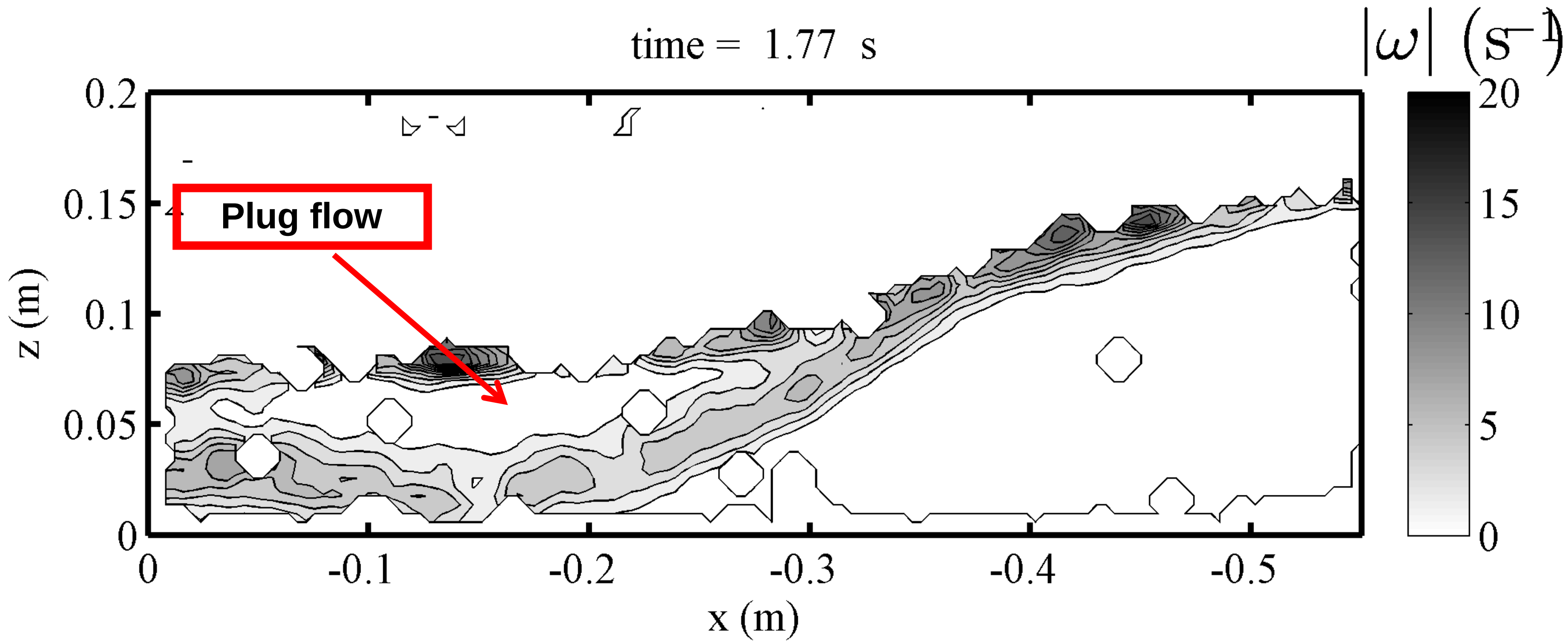
5. Results

Mass failure analysis



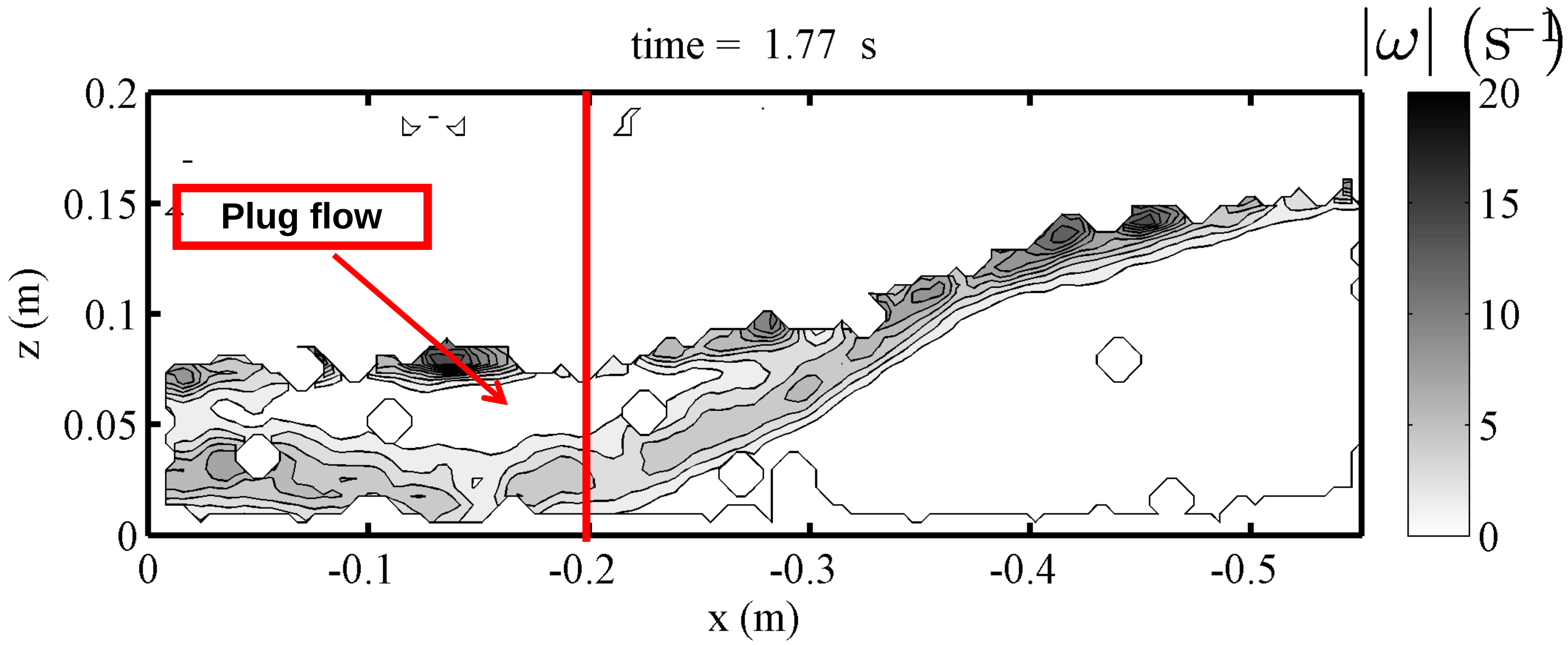
5.2 Detailed Analysis

Mass failure analysis

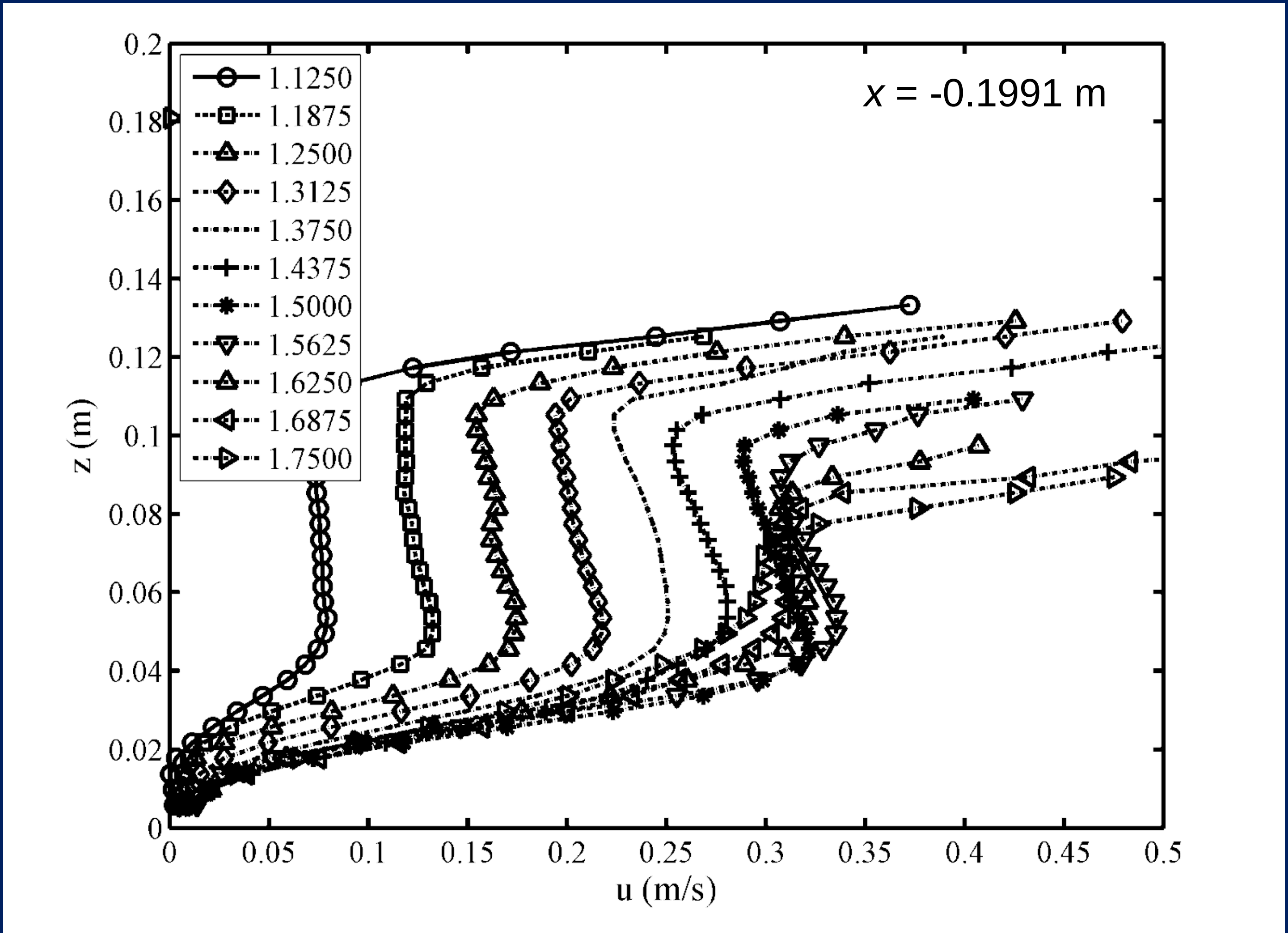


5.2 Detailed Analysis

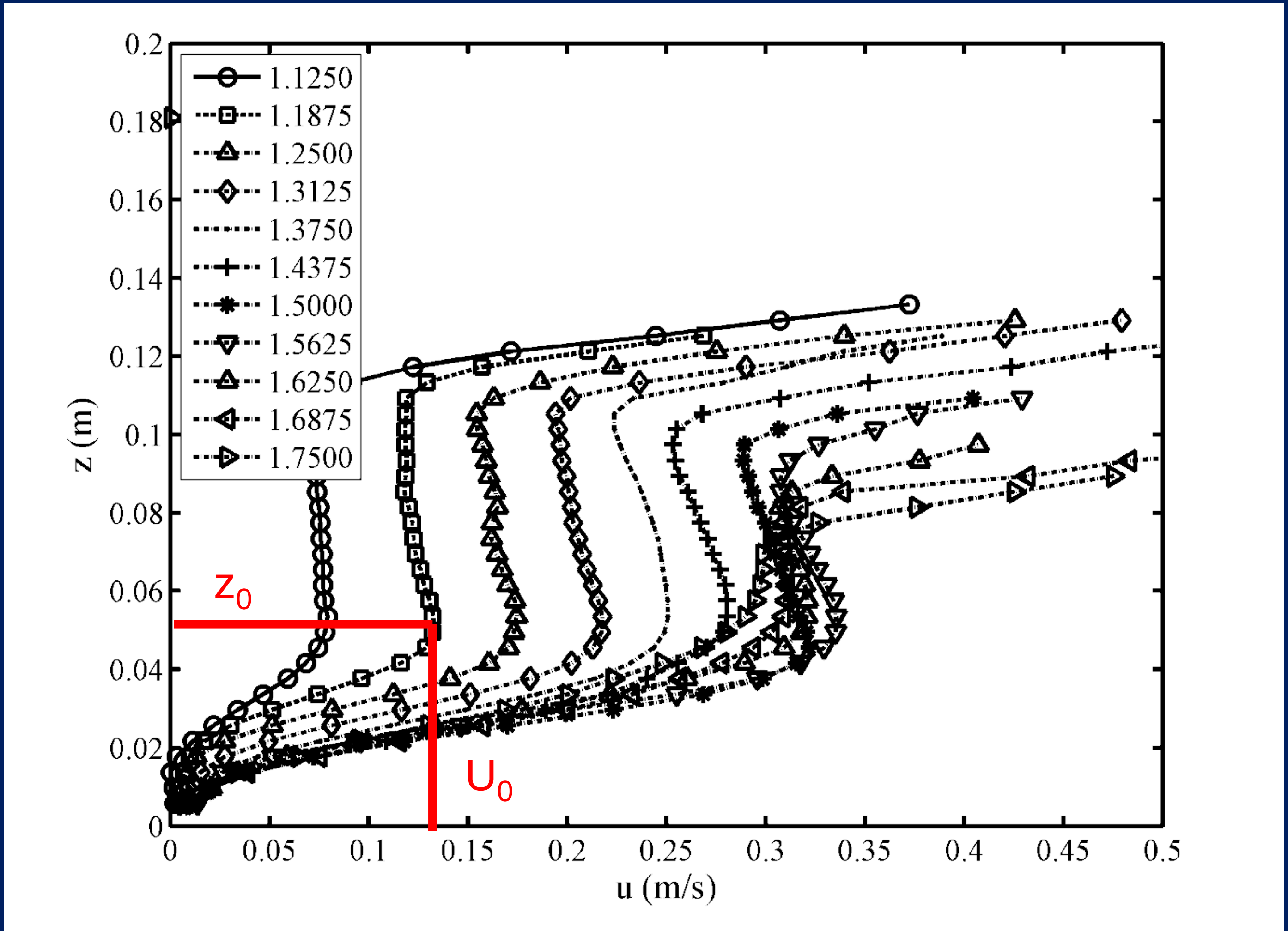
Plug flow analysis at *x* = -0.1991 m



5. Results

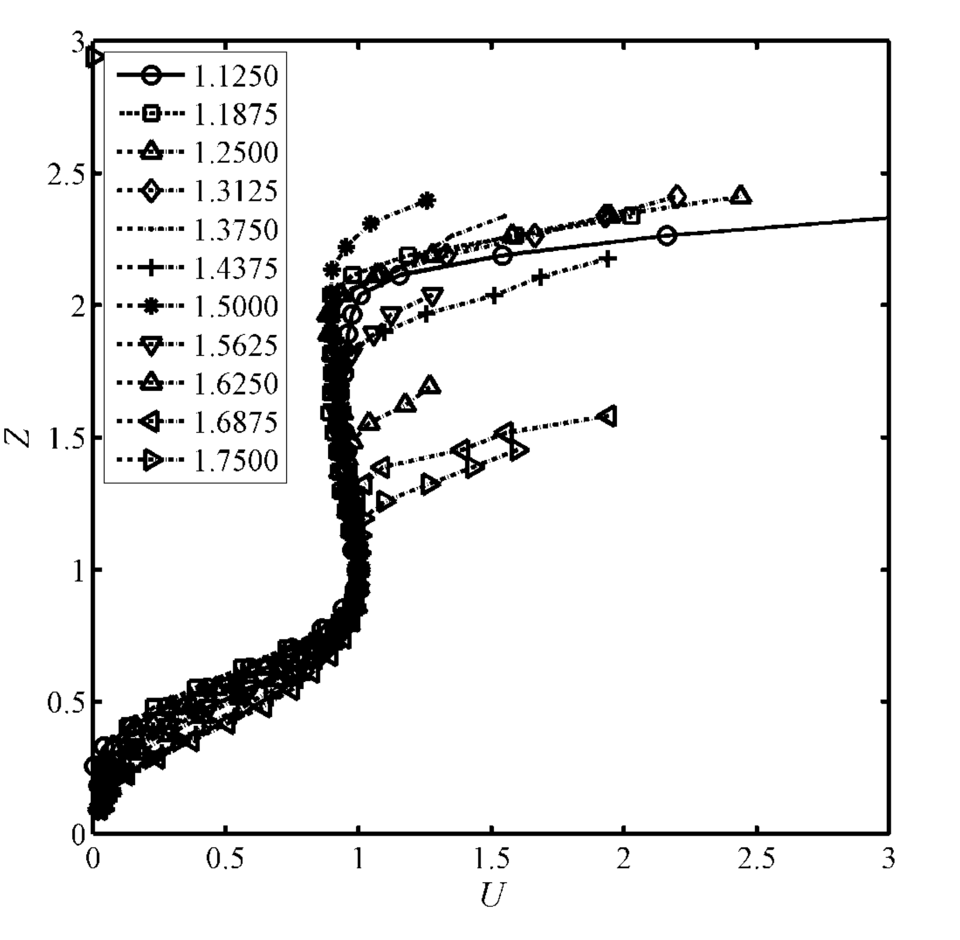

x = -0.1991 m
1.1250
1.1875
1.2500
1.3125
1.3750
1.4375
1.5000
1.5625
1.6250
1.6875
1.7500
z (m)
u (m/s)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

5. Results



Considering (U_0, z_0)

5. Results


1.1250
1.1875
1.2500
1.3125
1.3750
1.4375
1.5000
1.5625
1.6250
1.6875
1.7500
Z
U
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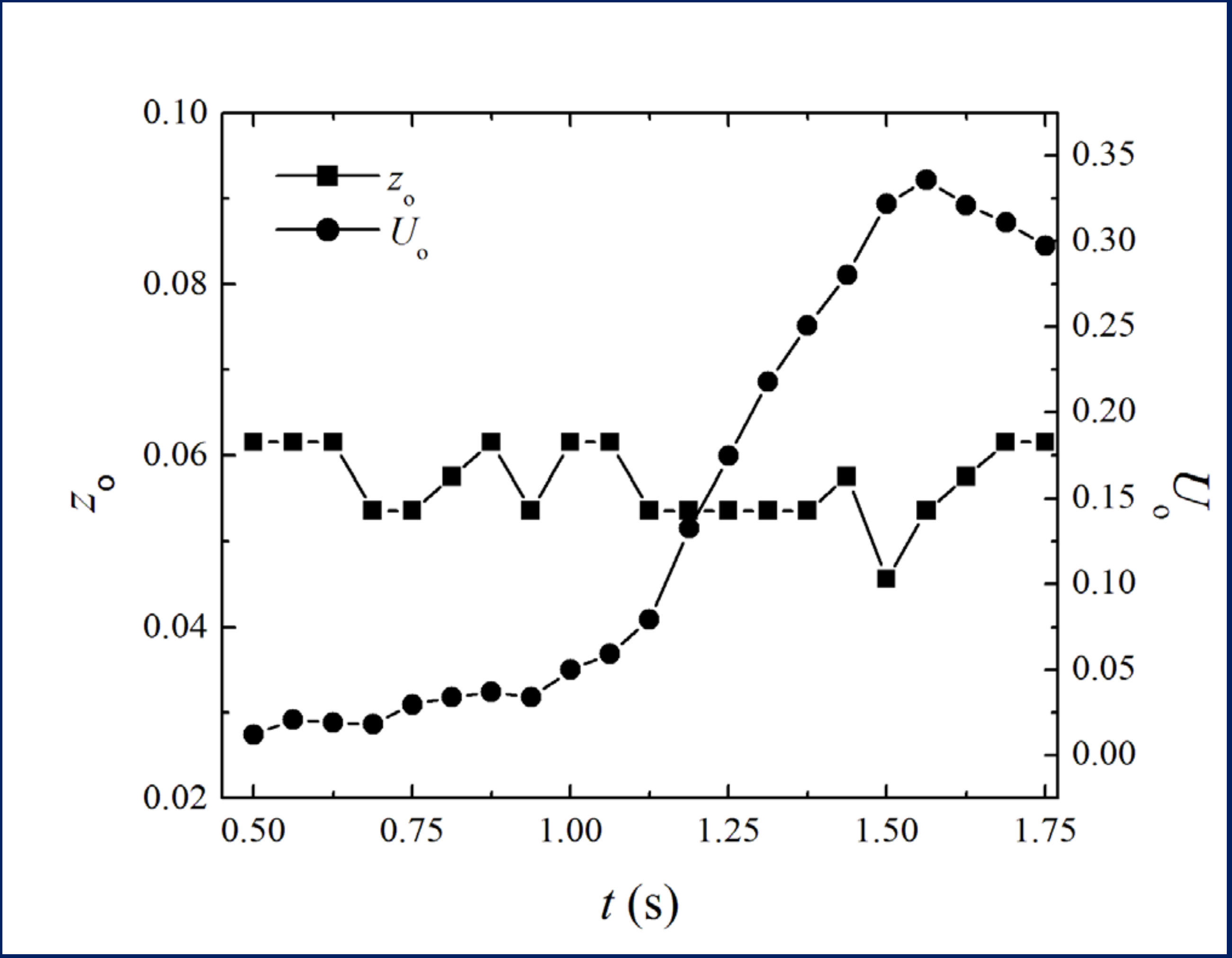
1
1.5
2
2.5
3

5. Results



0.10
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0.75
1.00
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1.75
t (s)

6. Conclusions & Future Work

1. The **combined PIV-PTV** approach was **able to detect and track** particles in the **different velocity scales** of this particular case of debris flow.

2. Using the proposed combined approach it was observed that it was possible to successfully track more particles than by using just PTV. It was also verified that a **linear interpolation** scheme allowed for more particles successfully tracked than the other tested scheme.

3. In the presented study of the tailings dam flow it was possible **to identify and quantify different features of the flow**. In the **first instants**, after the gate removal, the sediment flows is processed in two main ways:

a) **as sheet flow** (*upper* sediment layer);

b) **as a low velocity plug flow** (sediment bed).

6. Conclusions & Future Work

4. As time evolves, the water flow-bed interaction will cause the **appearance of a mass failure**. In this condition three flow layers were identified:

a) immediately close to the bottom a **shear layer with constant thickness** was observed. The maximum velocity of this layer increased almost linearly with time;

b) above this layer a **plug flow region with a constant velocity** was observed. This constant flow velocity profile increases with time until the plug flow region collapses;

c) an **upper sheet flow layer** in **the interface** between the **water flow and the sediment layer**. The identification of the different layers was made possible through the determination of the flow vorticity. Pertinent scaling variables for the upper transport layer and the mass failure region were determined.

6. Conclusions & **Future Work**

1. *Rollers*

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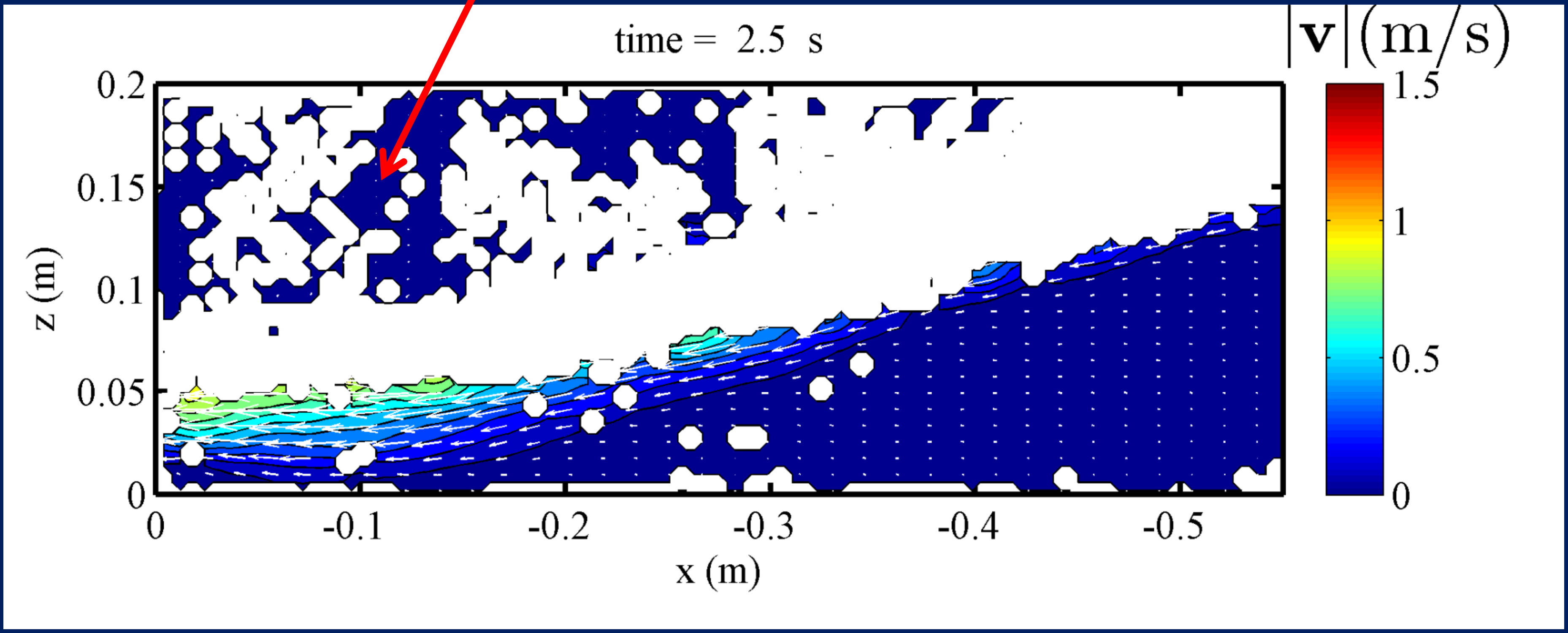
1. *Rollers*

6. Conclusions & **Future Work**

2. Automatic masking for PIV+PTV

Spurious flow field



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The End

Dziękuję za uwagę

Thank you for your attention.

Questions?