Sediment suspension events and structures at the transition between flow acceleration and stabilization

Fereshteh Bagherimiyab

André Roy

Ulrich Lemmin

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

University of Waterloo

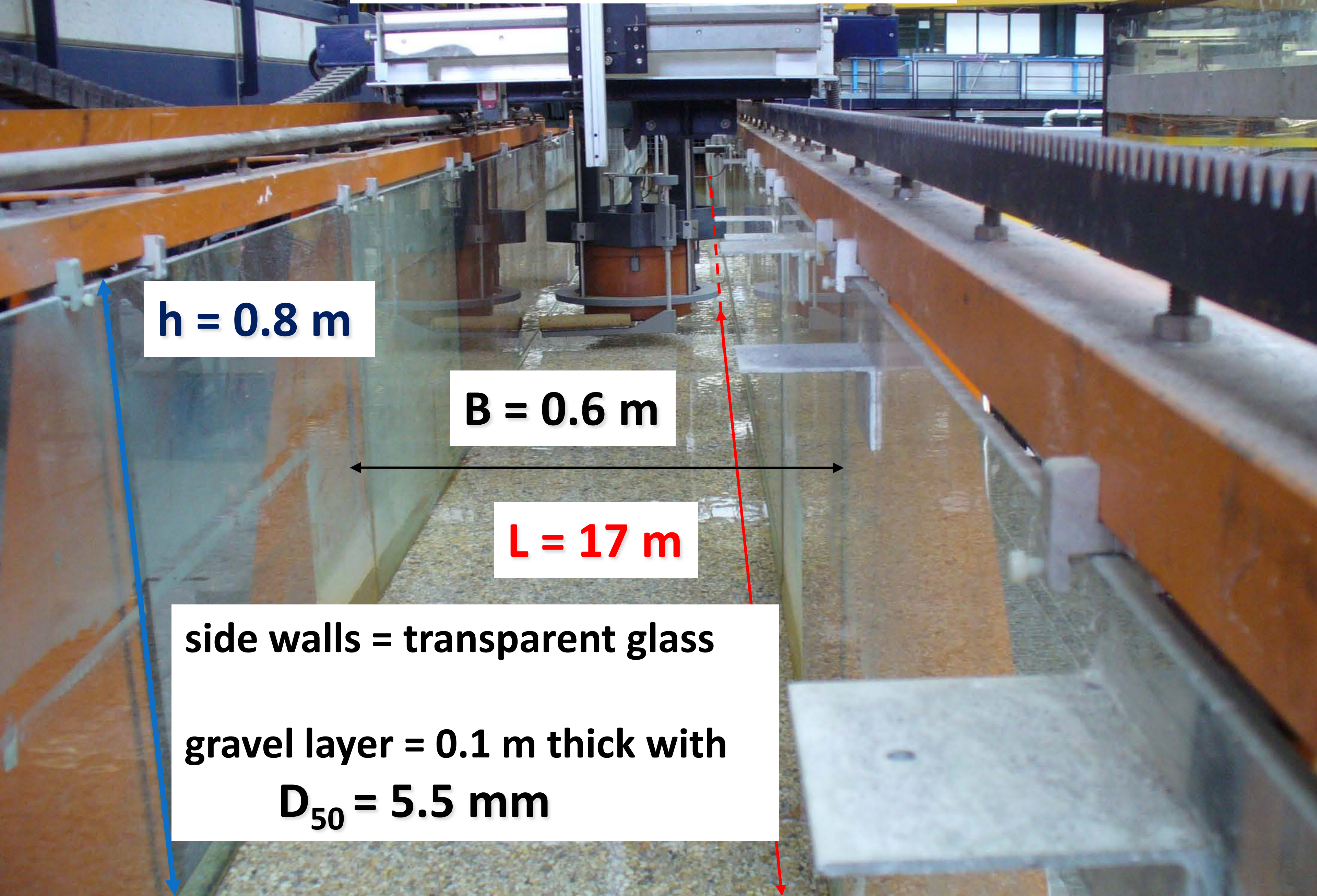
Introduction

- ❑ Flows in rivers are turbulent and often unsteady
- ❑ Most sediment transport in rivers tends to occur during unsteady flows such as during flood events
- ❑ Suspension of fine sediments
  - ➢ generates bed forms
  - ➢ affects water quality in rivers
  - ➢ impacts on the environment

Research Questions

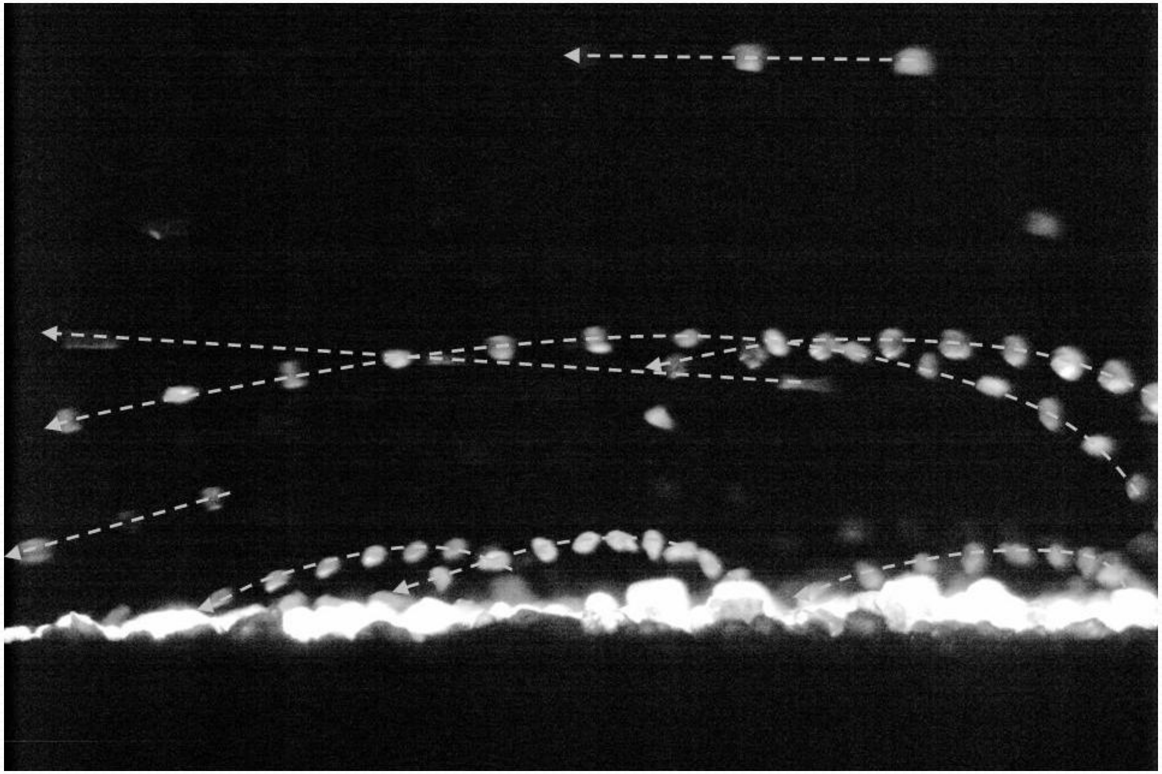
- How do suspended transport events change as the flow becomes unsteady?
- What are the interactions between suspension and bedform development as unsteadiness increases?

Experimental set-up

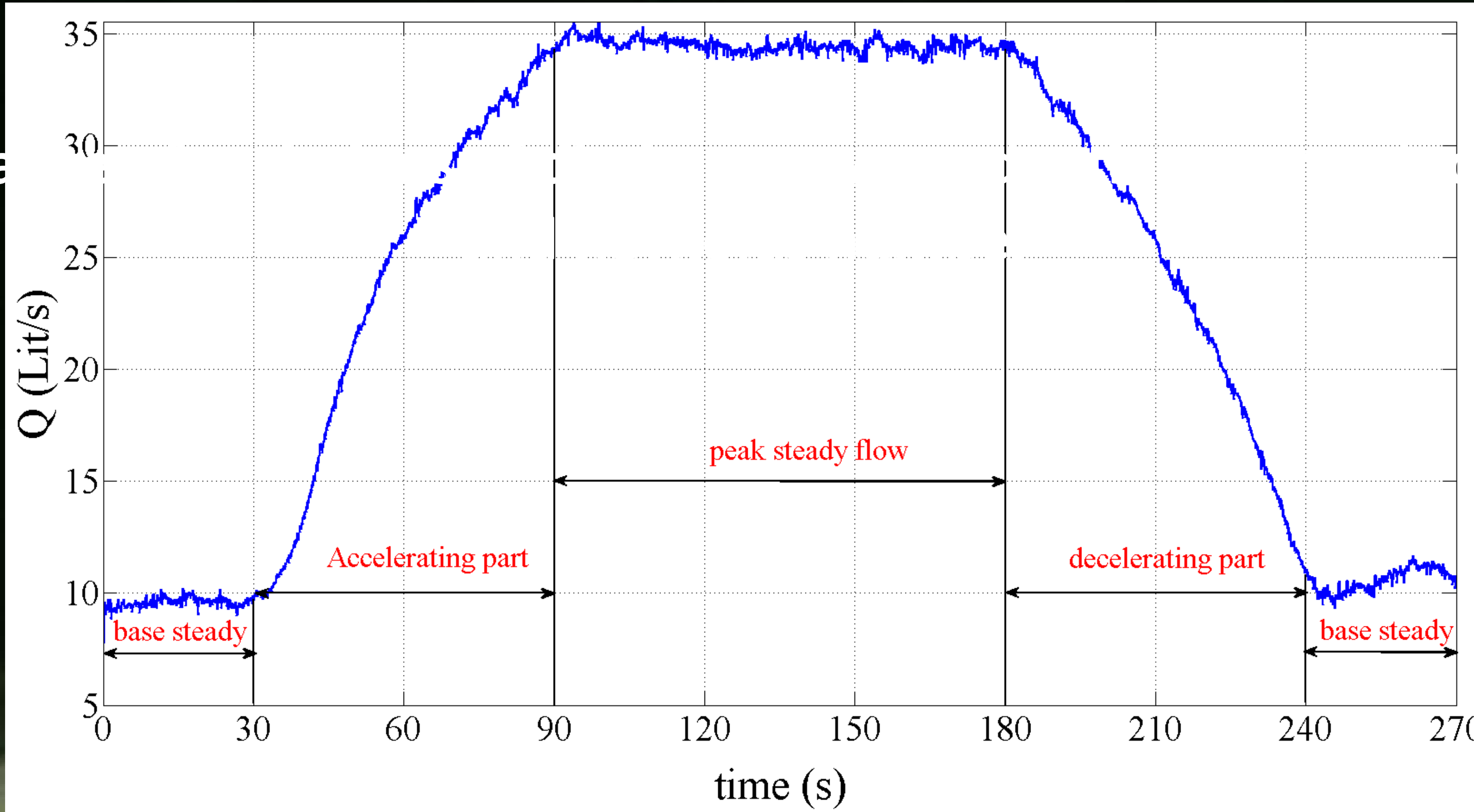


Experimental set-up

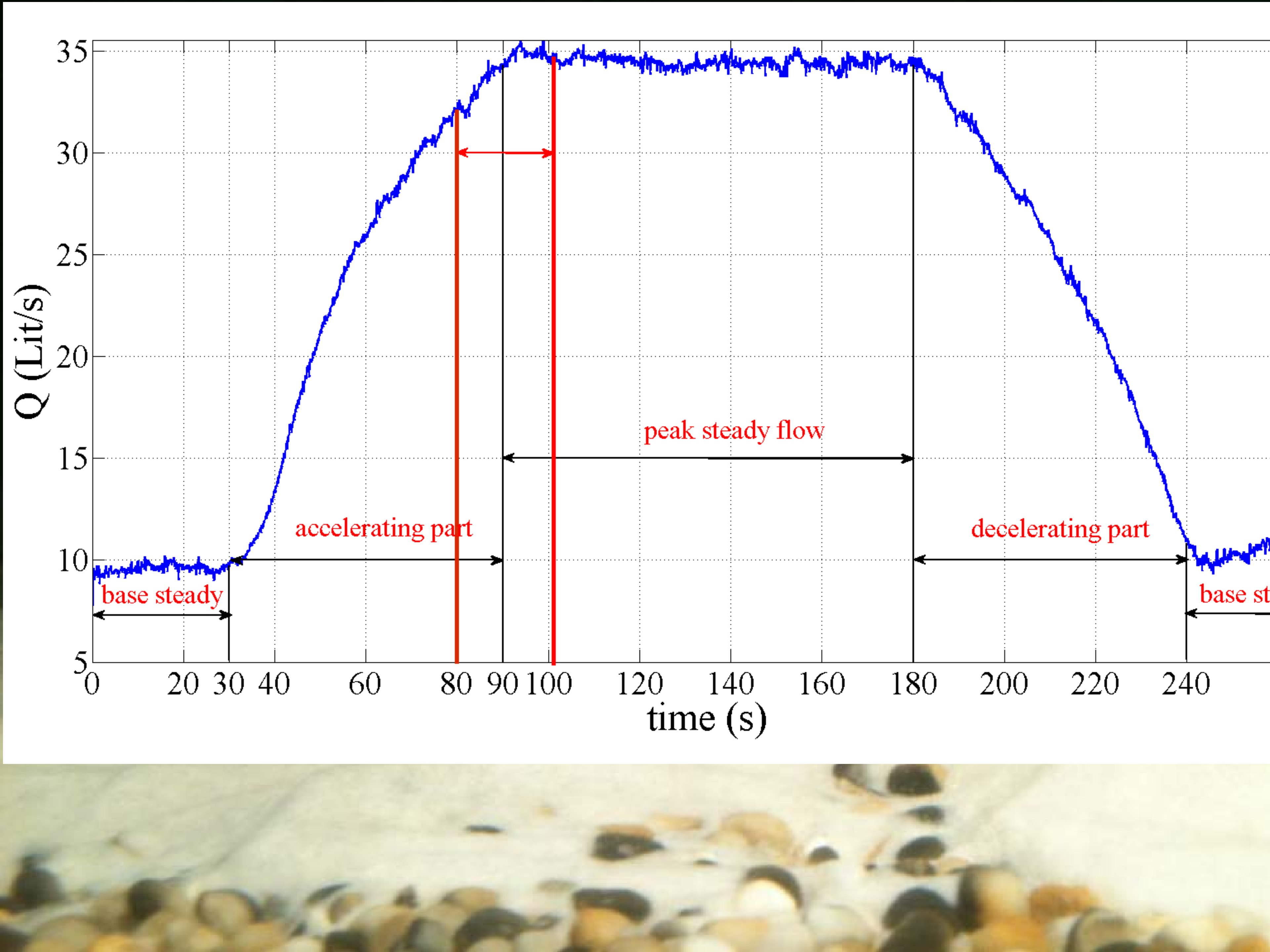
Particle Tracing Velocimetry (PTV)



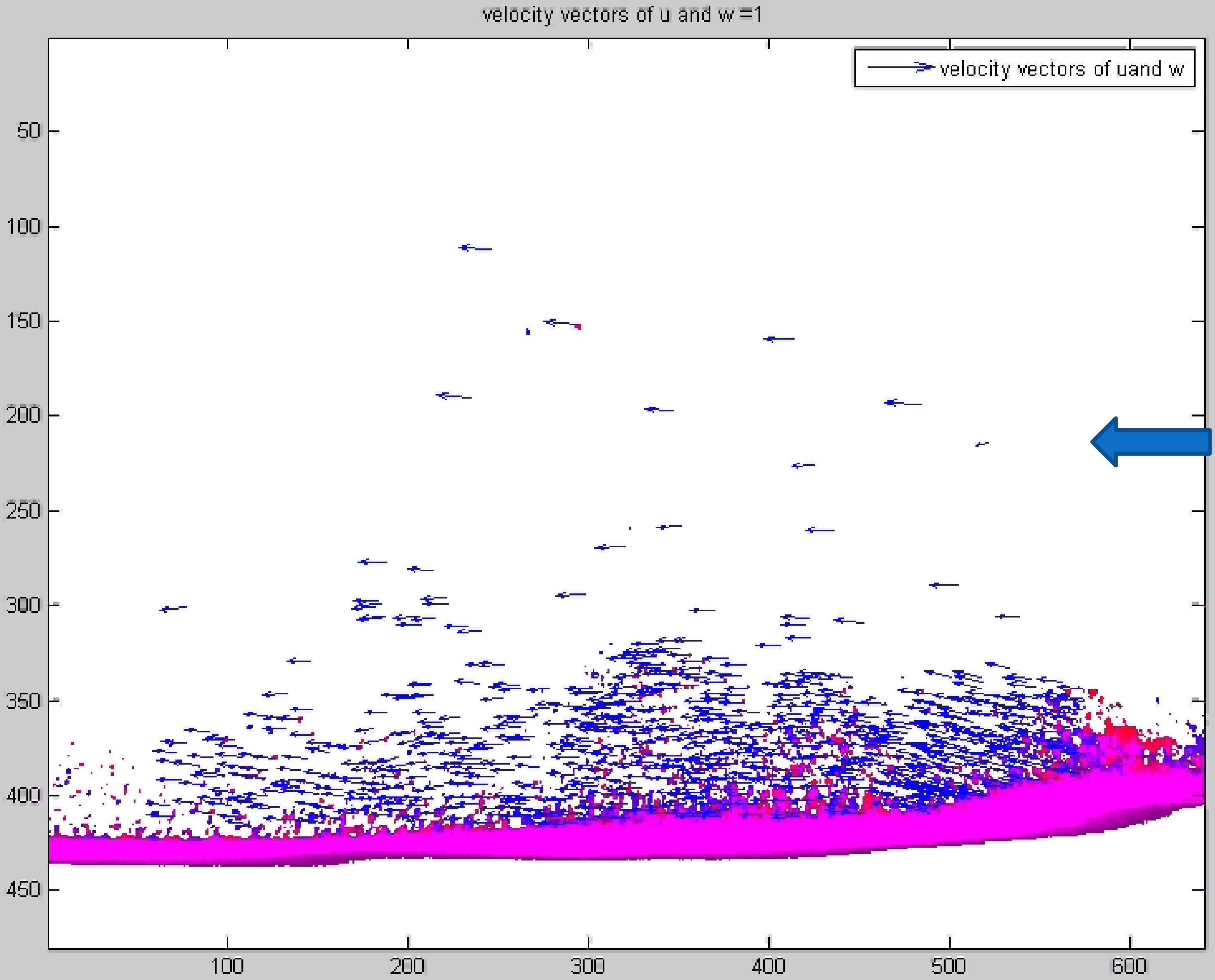
- Each individual particle is recognized and identified separately and tracked in time



Hydrograph:		Low	High
Pump discharge Q	($l\ sec^{-1}$)	10	35
Water depth h	(cm)	10.3	16.4
Mean velocity u	($cm\ s^{-1}$)	15	34
Reynolds Number		1.5×10^4	4.5×10^4

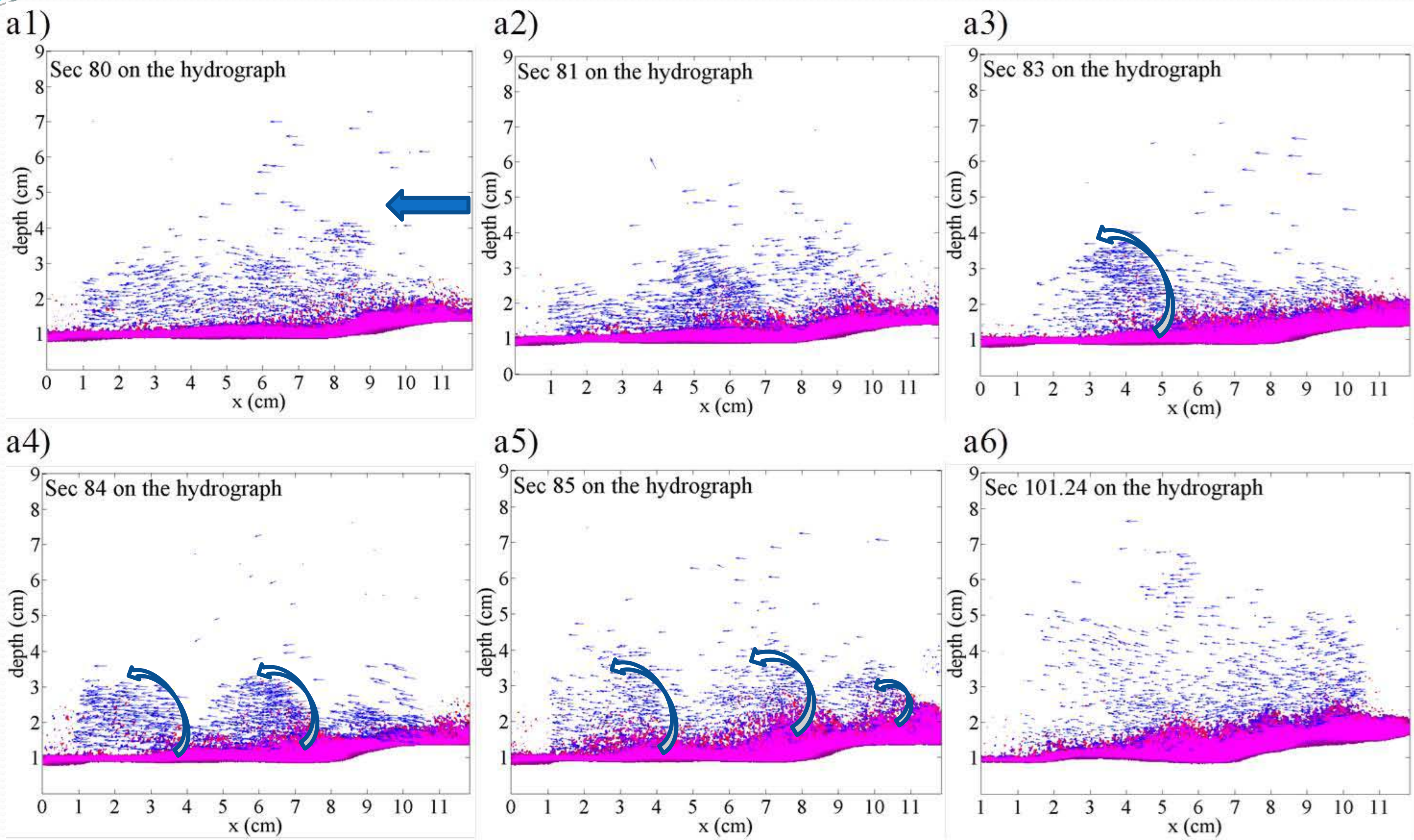


Q (Lit/s)
time (s)
peak steady flow
accelerating part
decelerating part
base steady
base st


velocity vectors of u and w =1
velocity vectors of uand w
50
100
150
200
250
300
350
400
450
100
200
300
400
500
600

Results

Example of PTV results during the final phase of the accelerating flow range



PTV velocity vectors during 21.2 s covering the final phase of the accelerating and part of the peak steady range.

Results

Close-up view of sediment particle trajectories related to ripple formation

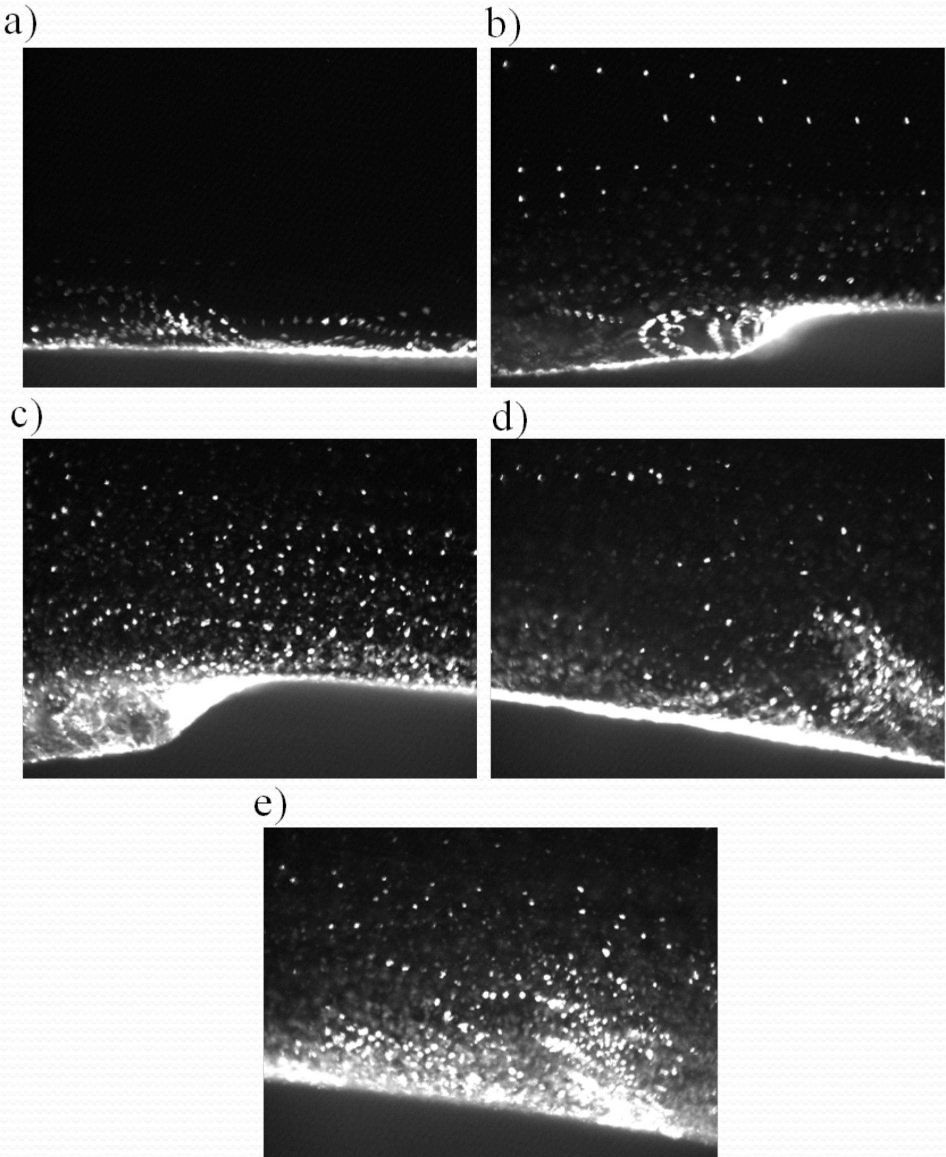
- ❑ During the initial saltation of particles, the upper layer of the whole bed began to move (Fig. a)

- ❑ Ripples started forming about 3 to 4 s after saltation started (Fig. b)

- ❑ A vortex is formed in the lee side of the crest (Figs. b and c)

- ❑ The vertical velocity component is strong in bursts in the near bottom layer on the back of the ripple (Figs. d and e)

- ❑ Difference between short and long ripples on suspension intensity

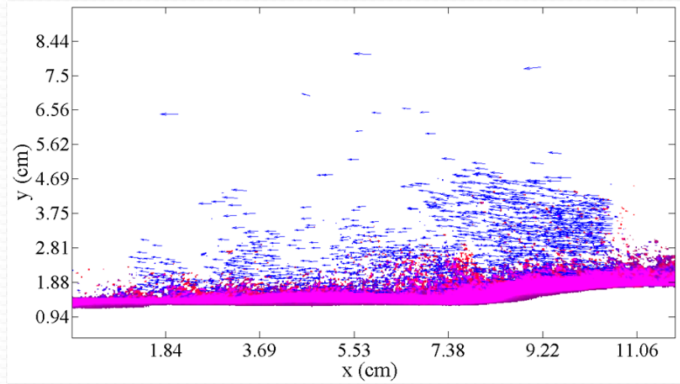


Results

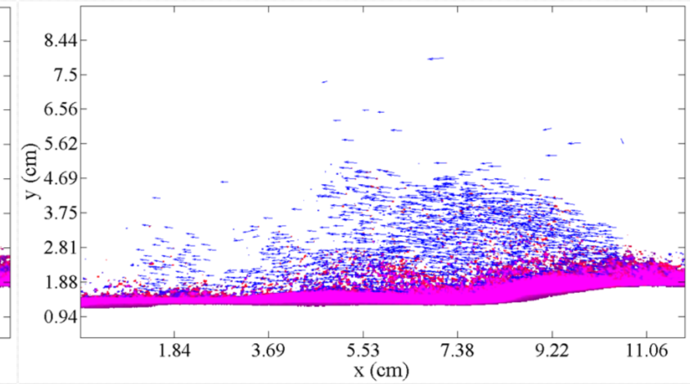
Effect of ripple on suspension during the final phase of the accelerating flow range

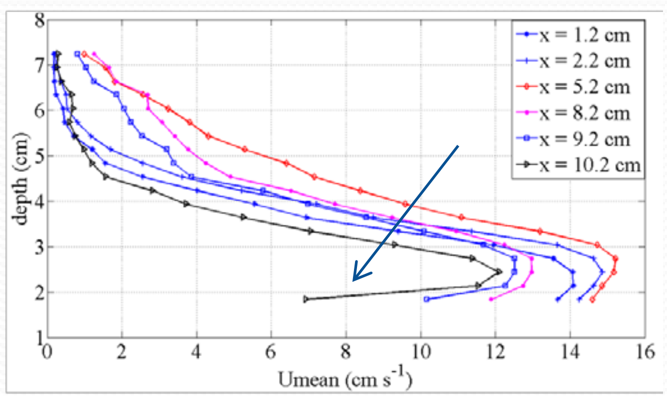
- ❑ Burst structure of suspension
- ❑Velocities are similar in crest and trough
- ❑ Highest concentration found where ripples are formed (x = 10.2 cm) with a strong gradient towards the trough
- ❑ Strongest bursts near the ripple crests

a)

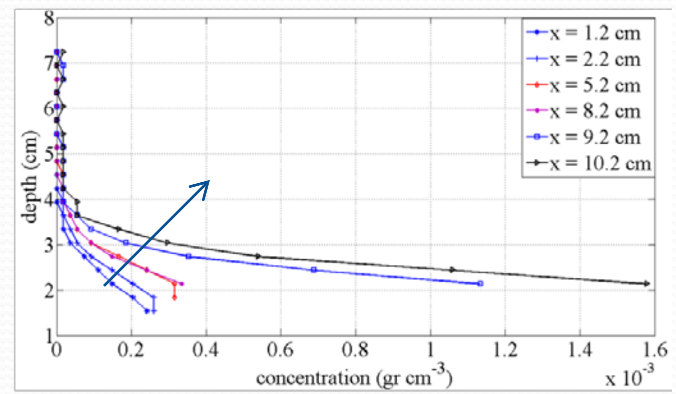


b)

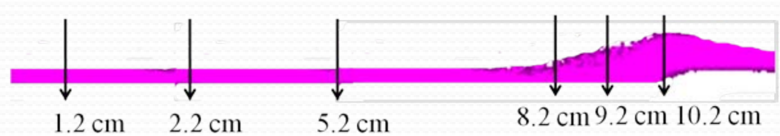




Particle velocities in six positions of images



Particle concentrations in six positions of images



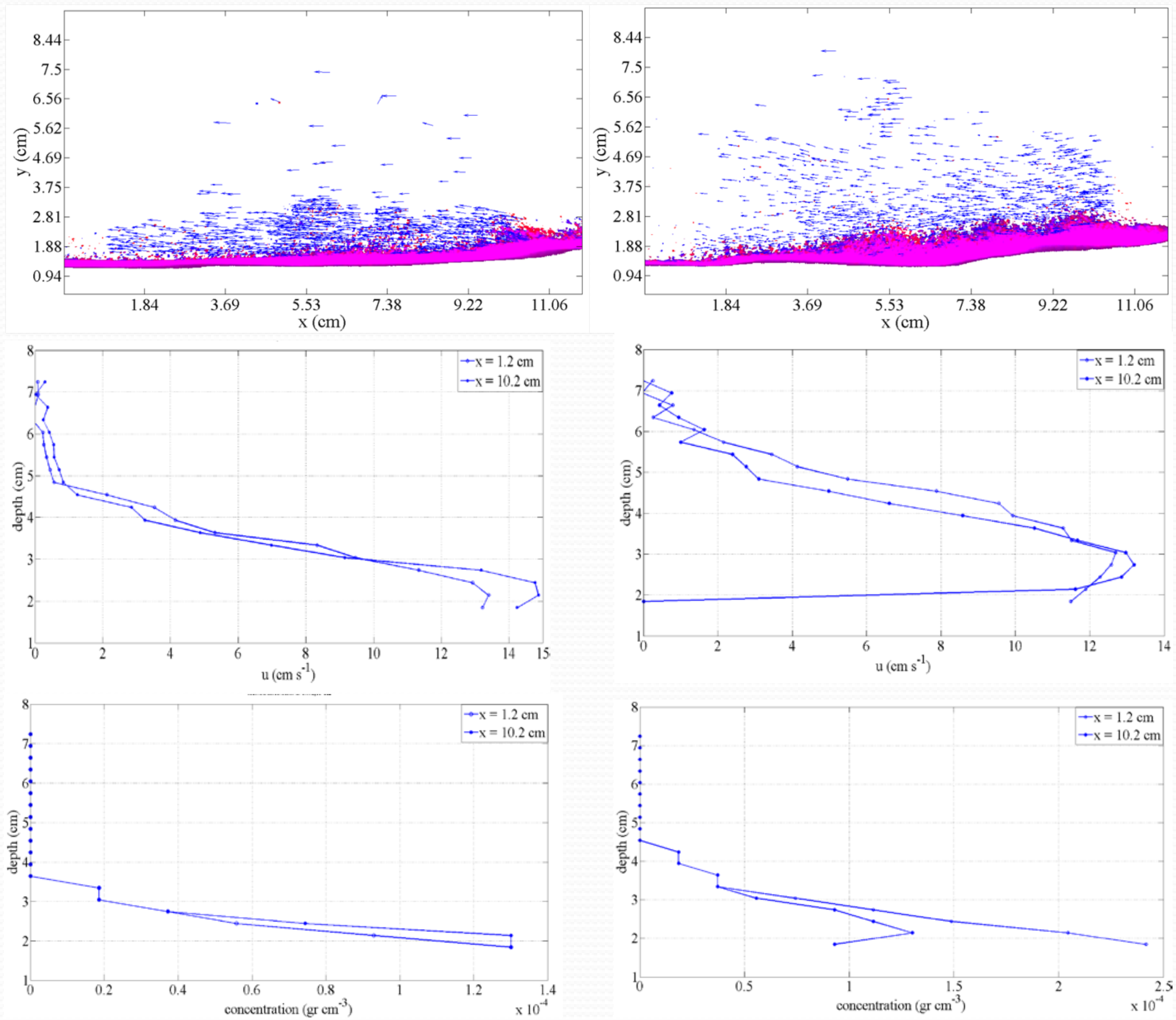
Bed form formation during the final phase of the accelerating flow range

Results

Difference between initial and final phase of the accelerating range

- ❑ Particle velocity profiles extend higher into the water column in the final phase
- ❑ The highest concentration is found near the bottom
- ❑ Total suspension, increase in the final phase. This confirms the importance of burst structures with strongest bursts near the ripple crests

a) initial b) final



Conclusion

In unsteady open-channel flow

- Sediment suspension dynamics near the bed is strongly characterized by burst events and by the presence of ripples .
- The height and intensity of the upward suspension were related to ripple dimensions.
- Ripples did not change in appearance or dimension for the duration of the experiments.
- Flow unsteadiness increases suspension sediment in water column.
- High sediment suspension continued to occur during the decelerating flow even though the flow velocity decreased.


Thank you for your attention

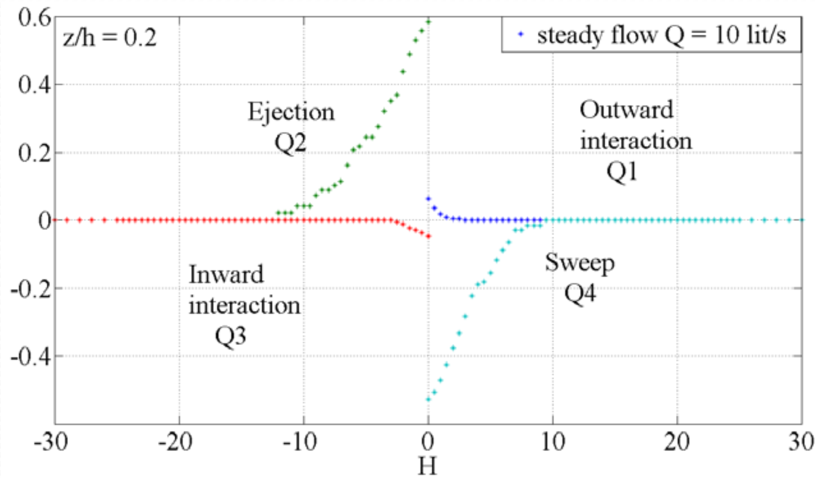
Conclusion

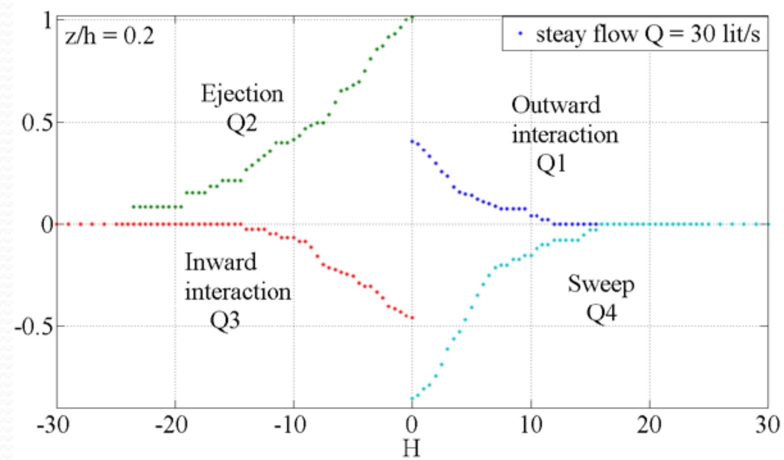
In unsteady open-channel flow

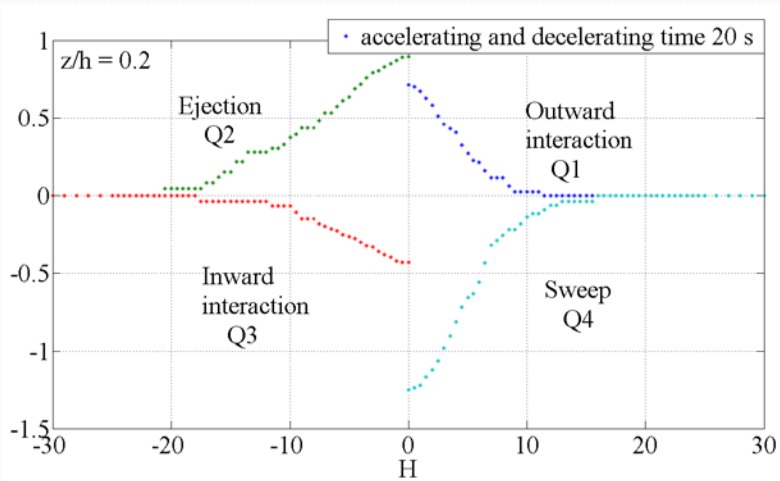
- Sediment suspension dynamics near the bed is strongly characterized by burst events and by the presence of ripples .
- The height and intensity of the upward suspension were related to ripple dimensions.
- Faster acceleration produced shorter ripples due to a much stronger friction velocity.
- Flow unsteadiness increases suspension sediment in water column.
- High sediment suspension continued to occur during the decelerating flow even though the flow velocity decreased.

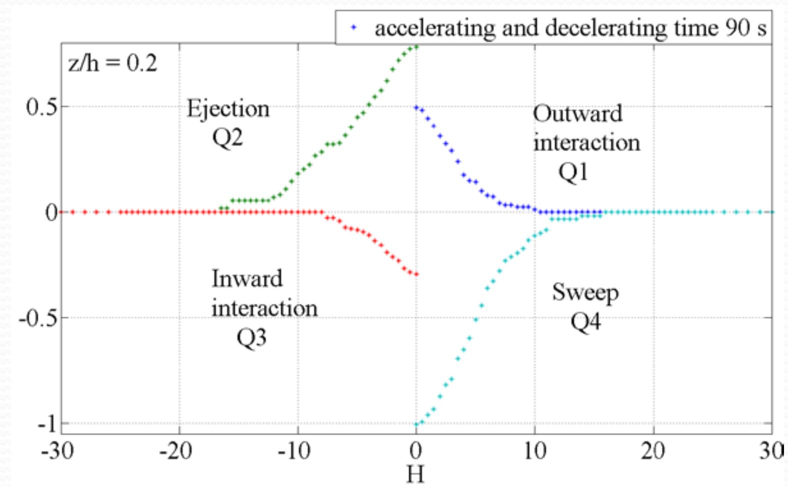
Results

Fractional contribution of relative covariance $e1 = u'w'/\overline{u'w'}$ versus threshold level H for ADVP data for the steady and unsteady flow



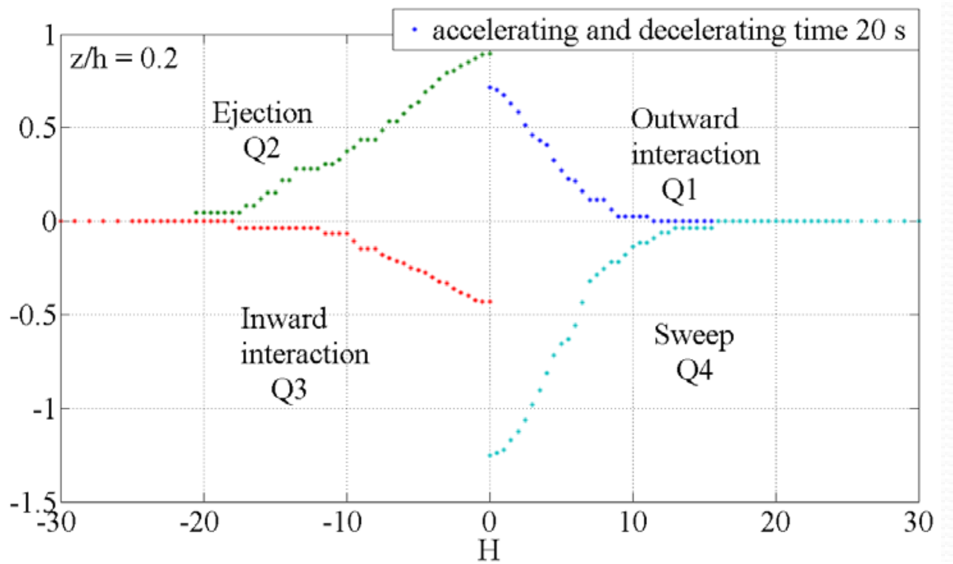


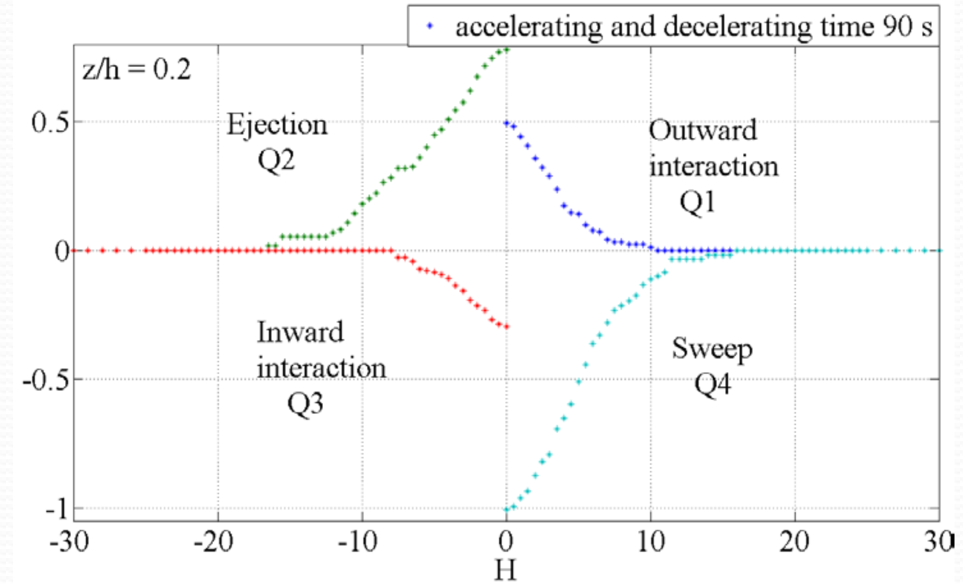


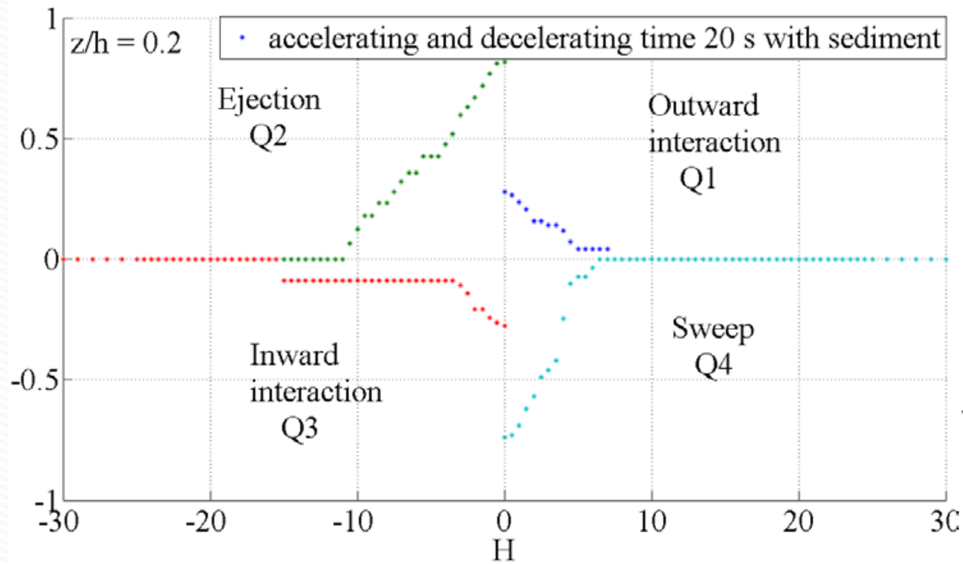


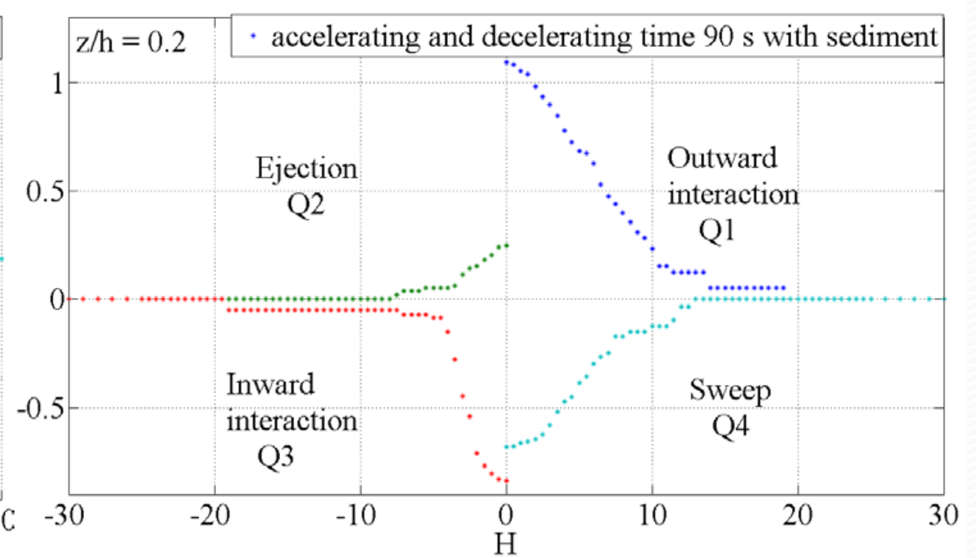
Results

Fractional contribution of relative covariance $e1 = u'w'/\overline{u'w'}$ *versus threshold level H for ADVP data for and unsteady flow*



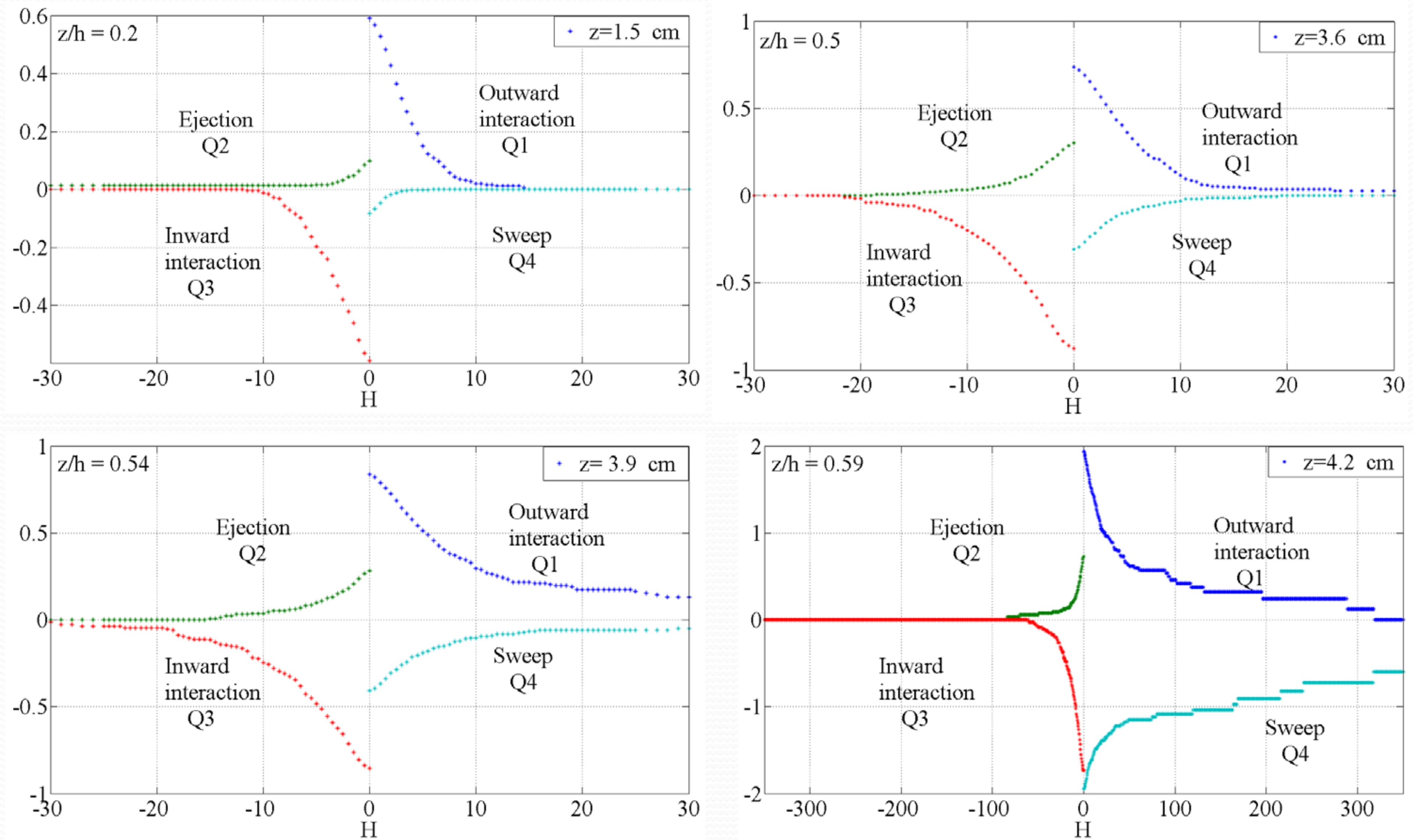






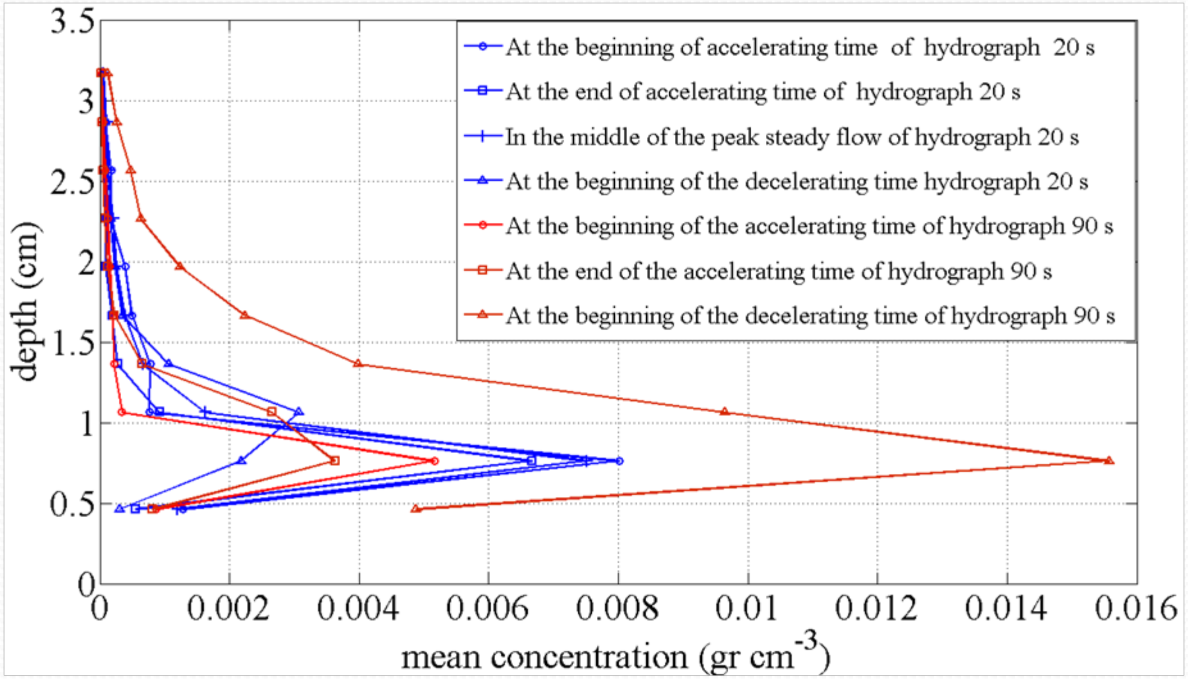
Results

Fractional contribution of relative covariance $e1 = u'w'/\overline{u'w'}$ *versus threshold level H for PTV data*



Results

Mean particle concentration for the different parts of the hydrographs for accelerating and decelerating time 20 s and 90 s



- ❑ higher suspension occurs for the hydrograph with 20 s accelerating time
- ❑ During the initial phase of the decelerating range of the hydrographs, a higher concentration is seen for the 90 s than for the 20 s hydrograph

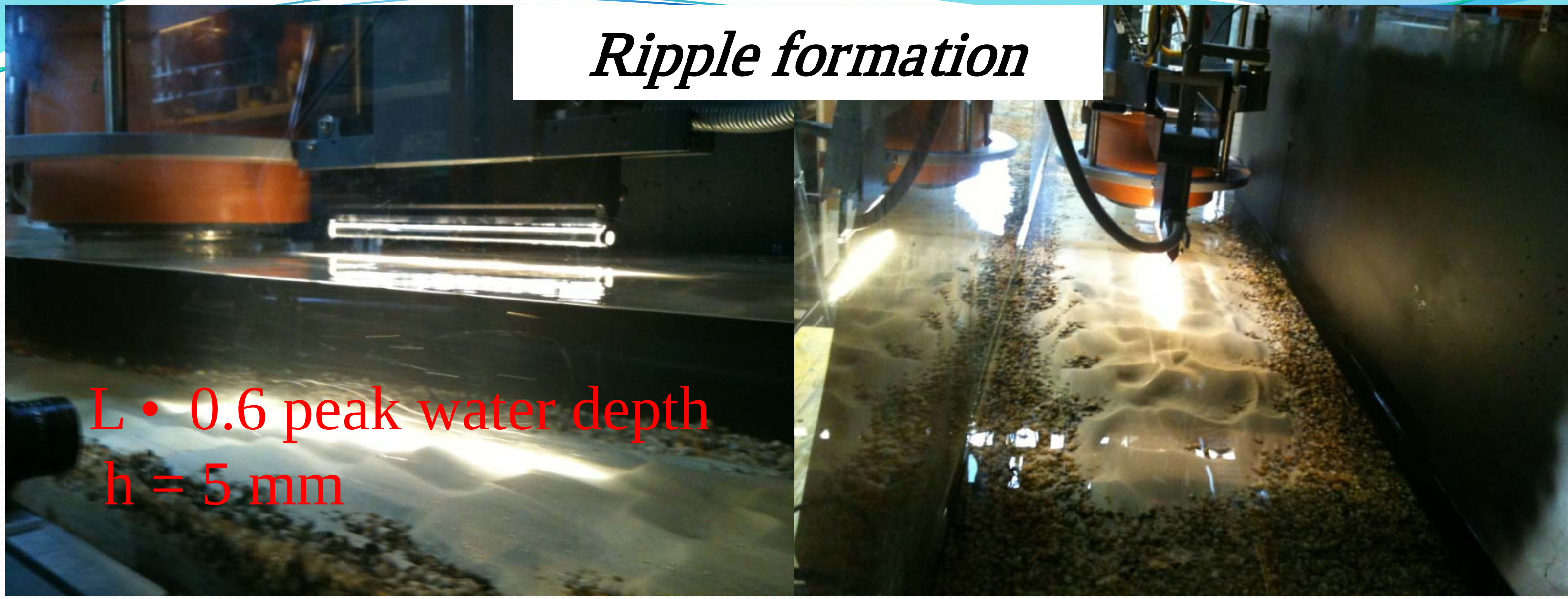
Flow with particle motion

Fine sediment dynamics in unsteady open-channel flow studied with optical systems

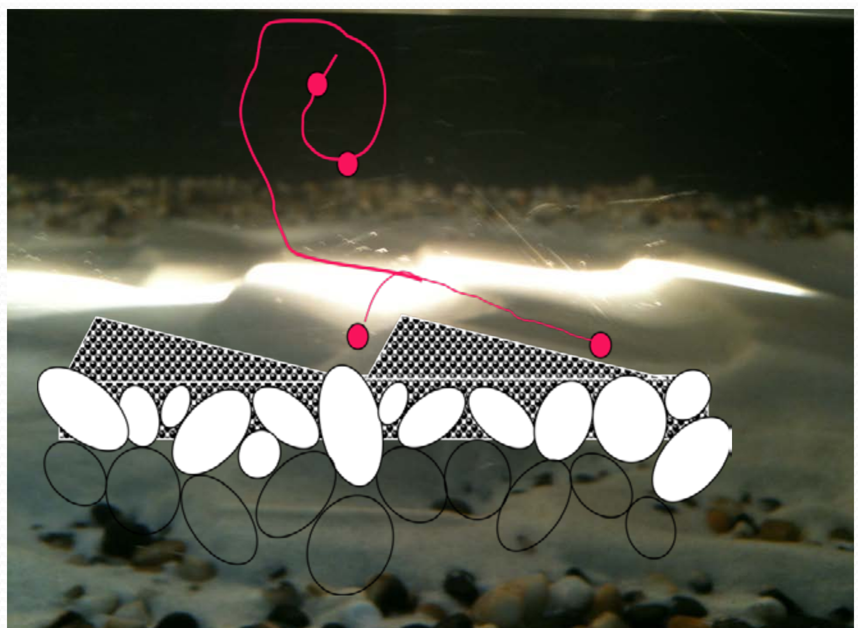
D_{50} = 0.12 mm

Thickness = 6 mm

Results



- ❑ Ripples formed quickly, within about 3 to 4 s after fine sediment particle saltation started



Fine particles rolled along ripples and some were suspended from the crest