XL International School of Hydraulics
23 - 26 May 2023 • Kąty Rybackie • Poland

A Lagrangian analysis of the surface flow in a jet dissipation basin at equilibrium

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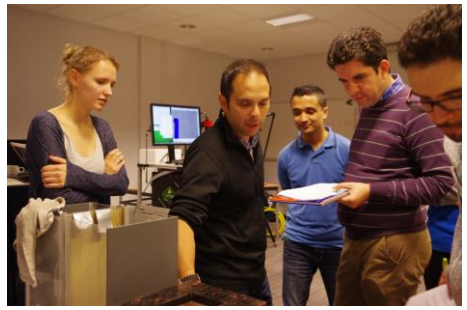
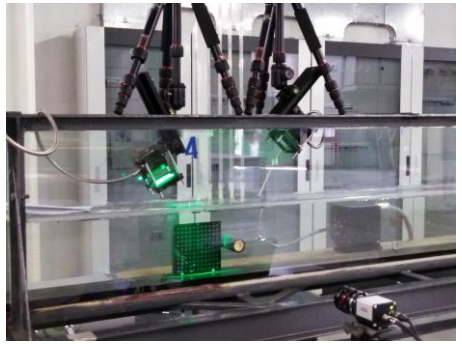
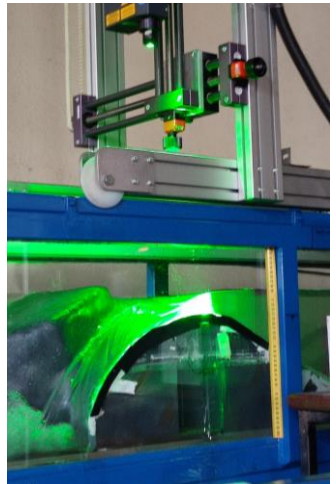
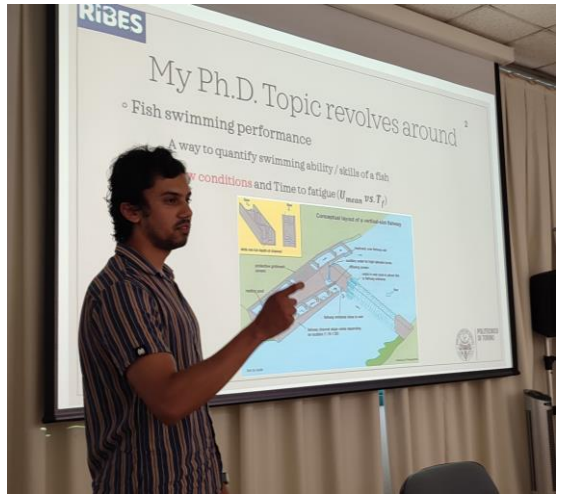
www.watersummerschool.wordpress.com









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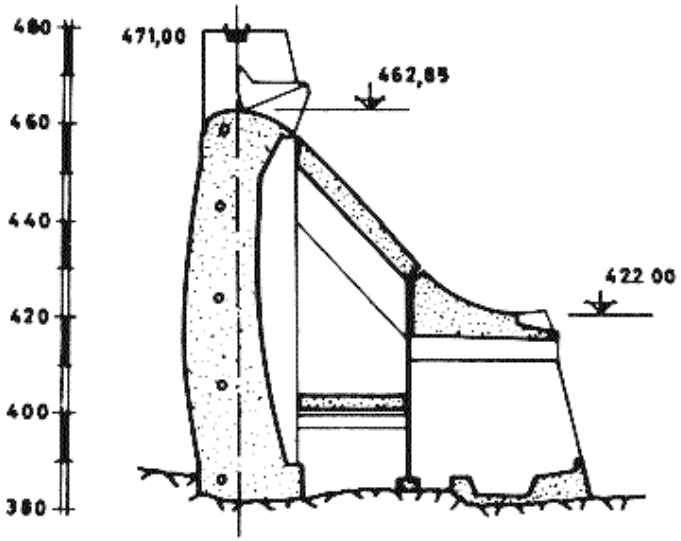
Energy dissipation downstream of hydraulic structures: using jets

https://www.tecnoplano.pt/sistema-de-energia/aproveitamento-hidroelectrico-do-douro-internacional-barragem-do-picote/

/https://en.wikipedia.org/wiki/Picote_Dam

Energy dissipation downstream of hydraulic structures: using jets

(a)



(b)

(c)

(d)

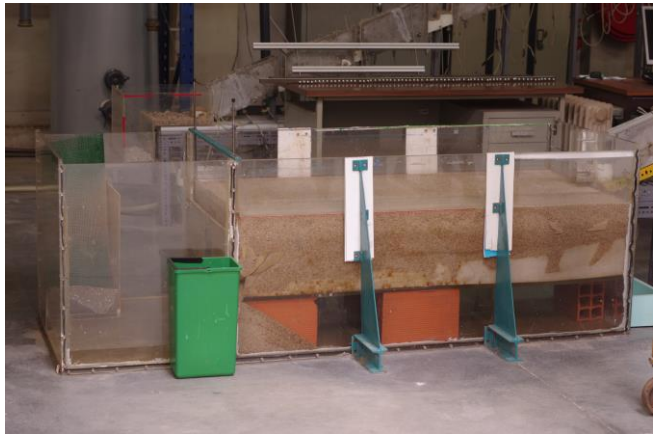
(e)

(a) scheme; (b) dam; (c); (d) ski jump; (e) Alqueva dam.

(http://cnpgb.apambiente.pt/gr_barragens/gbportugal/Lista.htm; http://www.construir.pt/2009/09/25/edp-investe-250-me-em-picote-e-bemposta/; http://picote.blogs.sapo.pt/arquivo/2005_11.html)

https://epod.usra.edu/blog/2013/05/alqueva-dam-portugal.html

Physical model: Stepped spilwway with a ski bucket at the exit

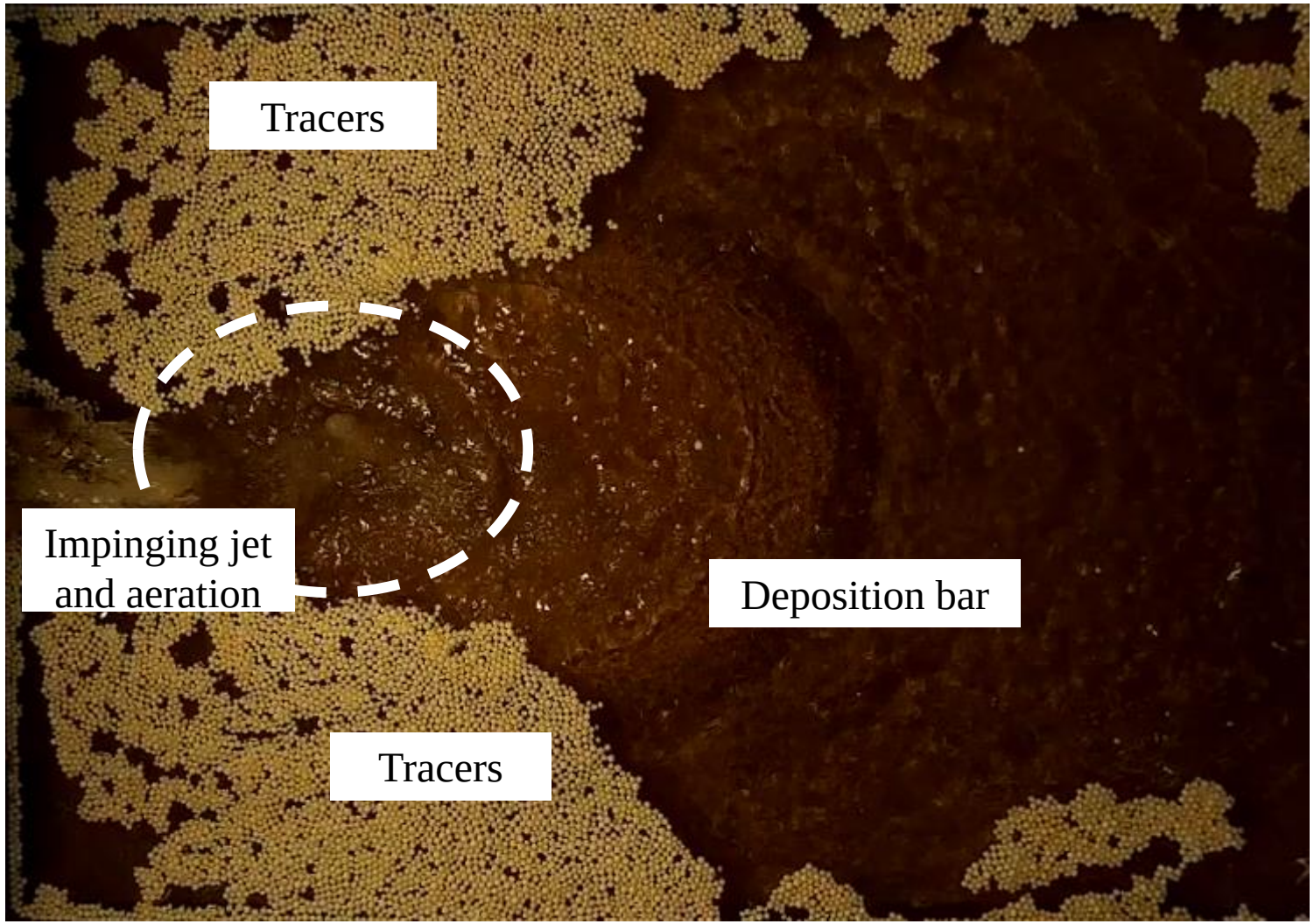


Scale 1:40 | 1 m high and 2.60 m length | 26 steps, each with 3.75 cm height and 10 cm long.
Ski bucket angle 20º

Flow pattern in the dissipation basin at equilibrium

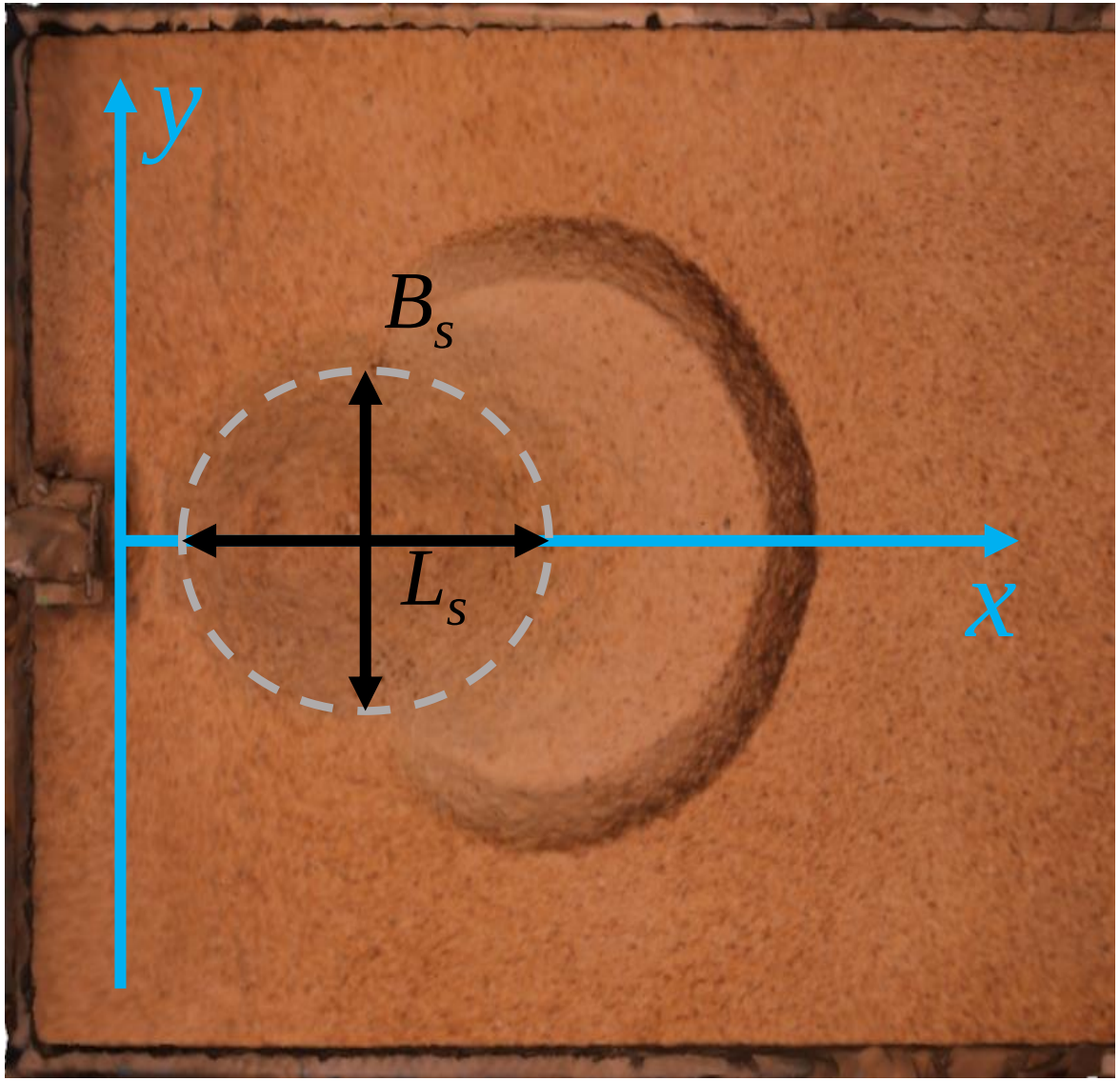
Flow pattern in the dissipation basin at equilibrium

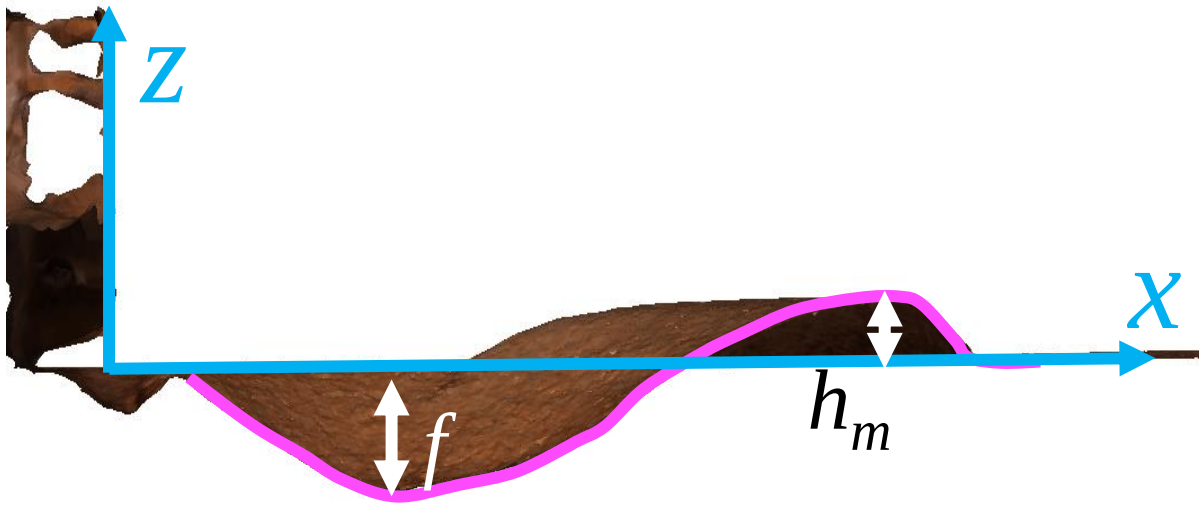
Flow pattern in the dissipation basin at equilibrium



At equilibrium: when no changes are observed in the bed

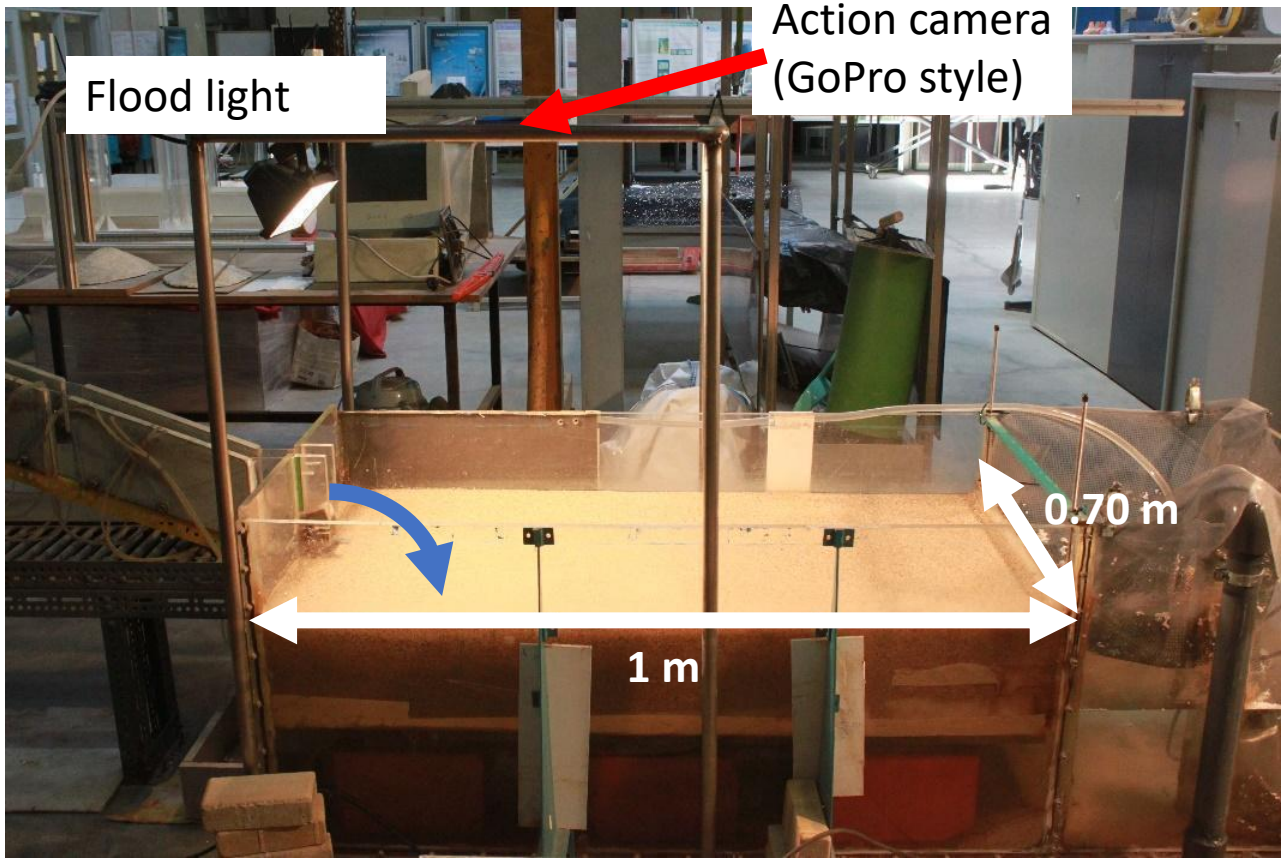
At equilibrium: when no changes are observed in the bed

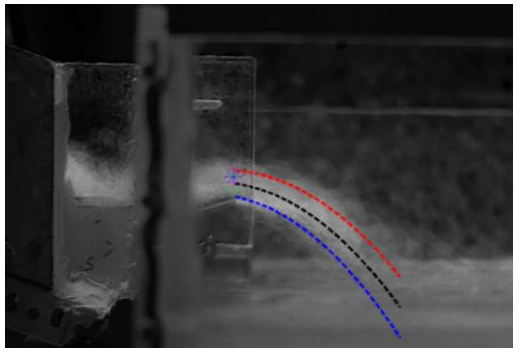




Equilibrium time: determined by trial: run experiment until no changes are observed in the bed.

Dissipation basin





Q = 0.85 L/s

ρ_w =998 kgm^{-3}

ρ_s =2650 kgm^{-3},
d_{50} =0.992 mm
d_{85} =1.75 mm
d_{90} =1.855 mm
σ_g = 1.68.

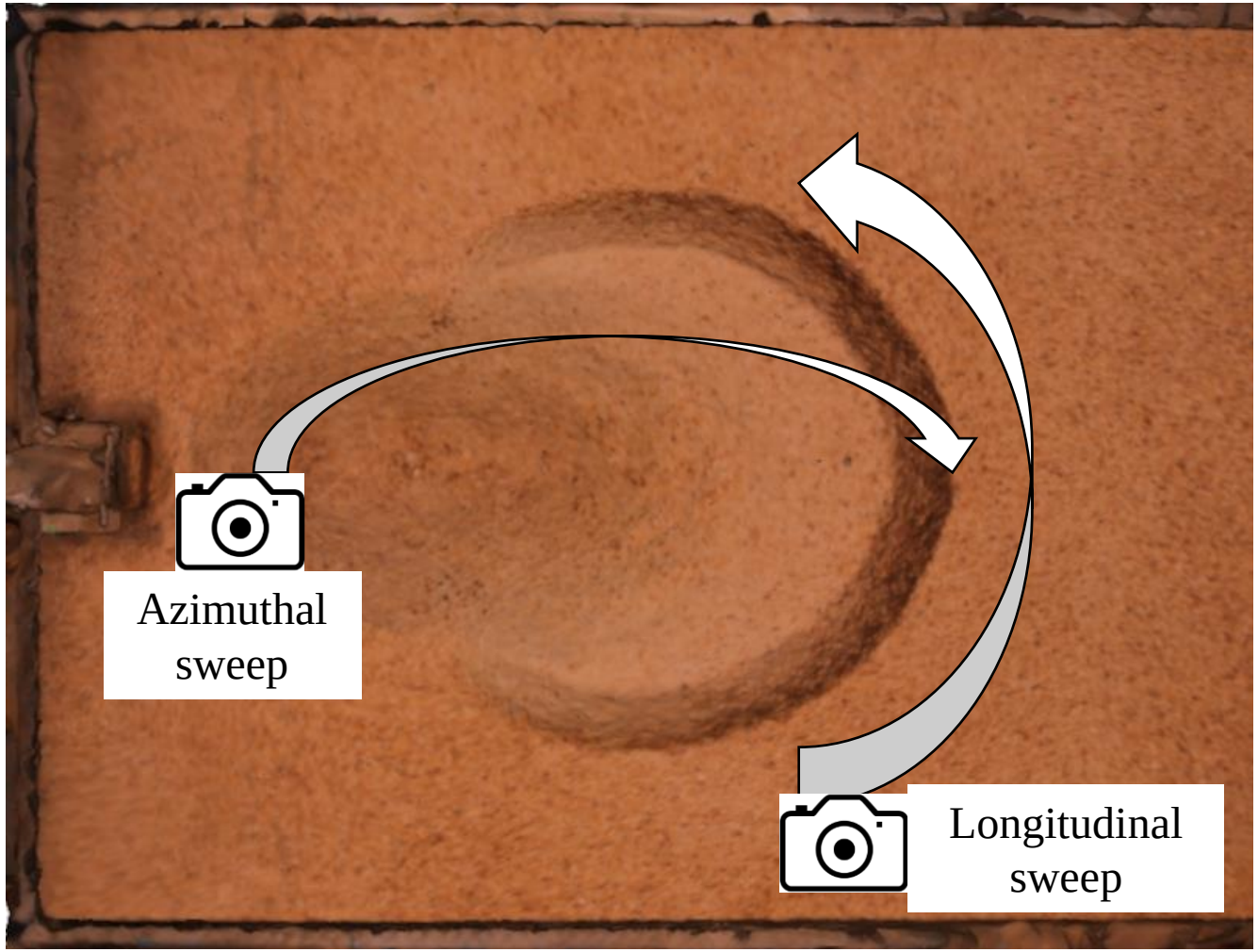
h_w = 0.05 m

h_s = 0.20 m

+ Canon EOS500D

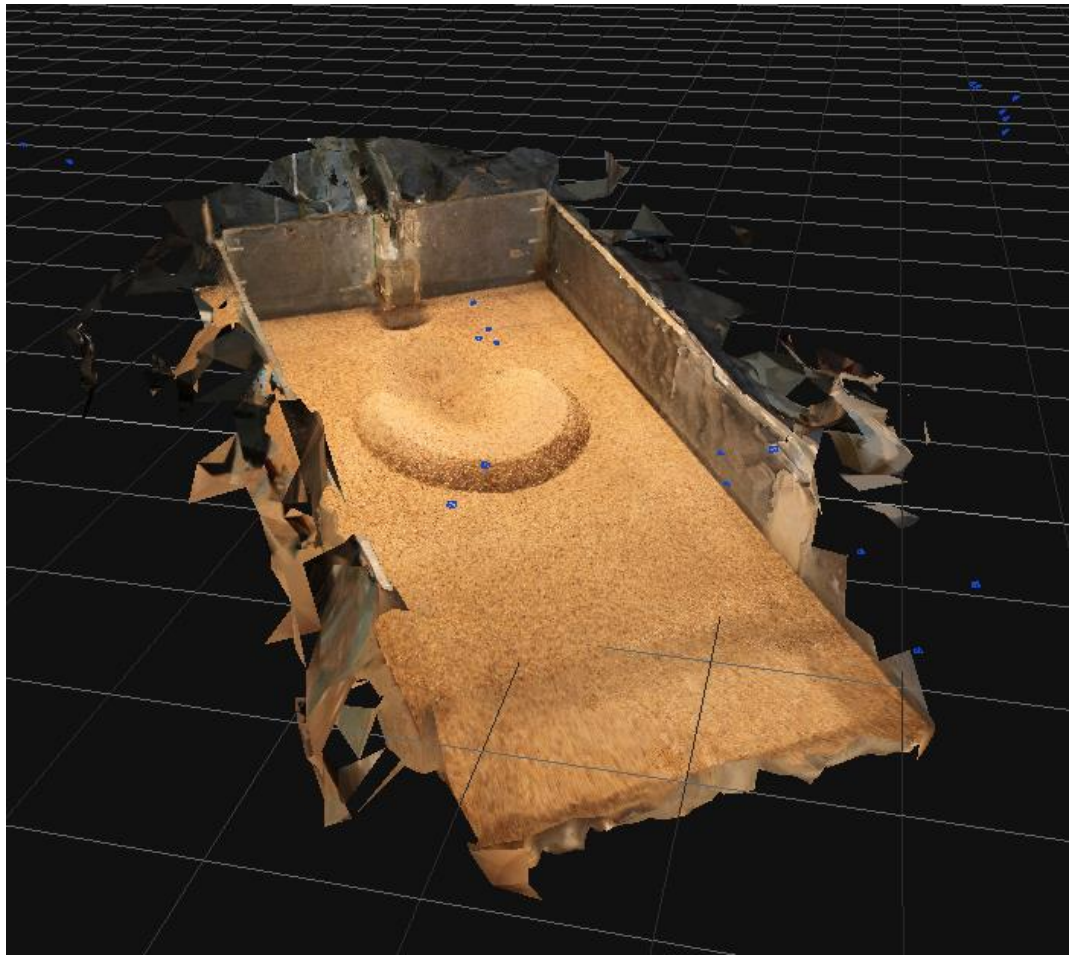
+ Electromagnetic flowmeter

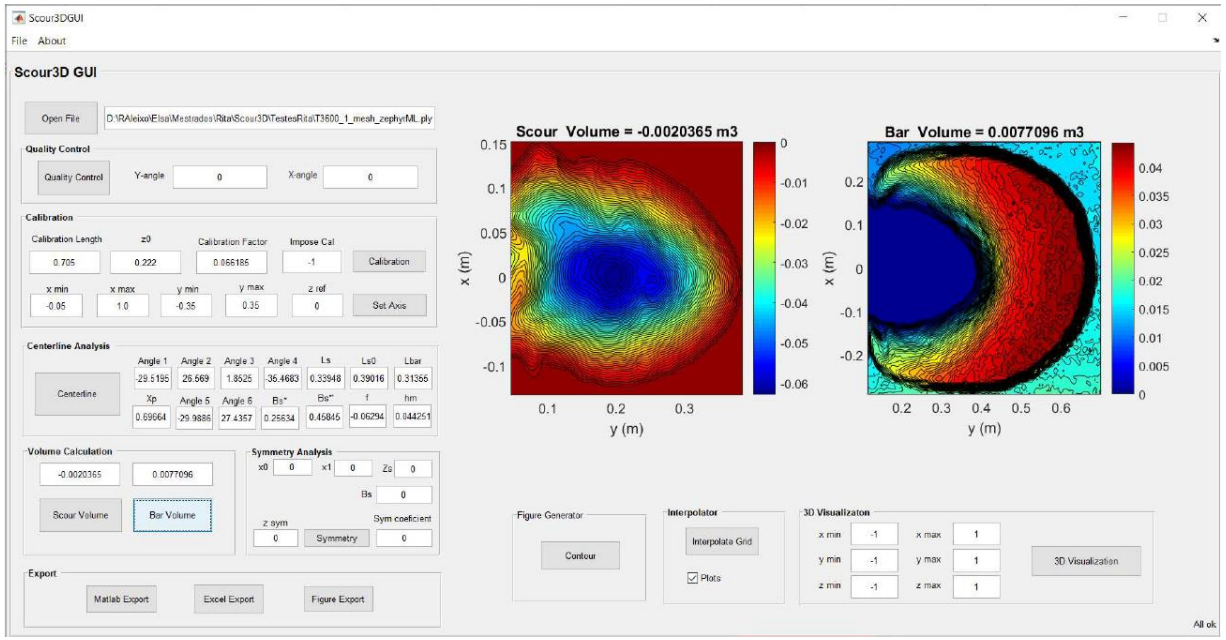
Geometry measurements: Structure from Motion [2,3,4]



Canon EOS500D + 50mm f1.7

Geometry measurements: Structure from Motion [2,3,4]





Scour3DGUI, [5]

f = -0.082 m
h_m = 0.03 m
V_S = 0.00318 m^3

Velocity measurements: Particle Image Velocimetry

Action Camera Turnigy (30 fps)

Velocity measurements: Particle Image Velocimetry

Action Camera Turnigy (30 fps)

Velocity measurements: Particle Image Velocimetry

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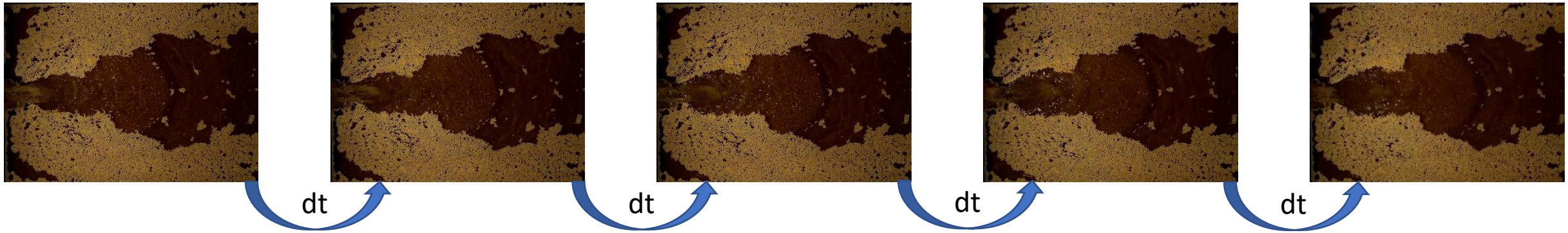
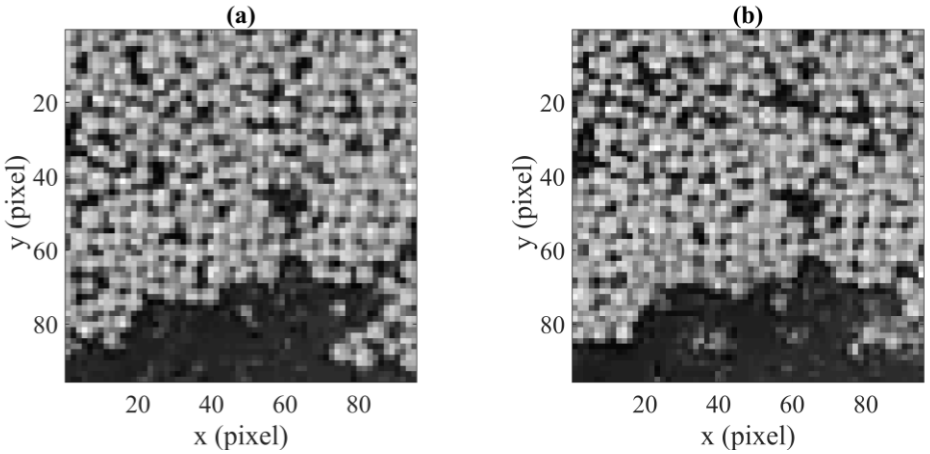
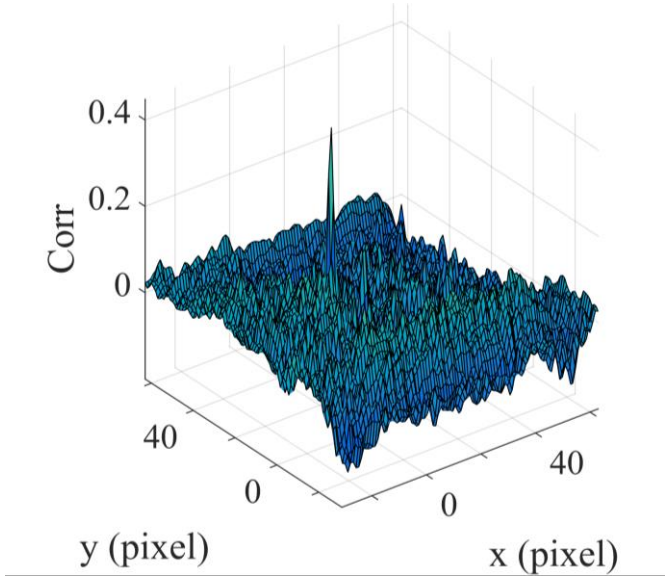
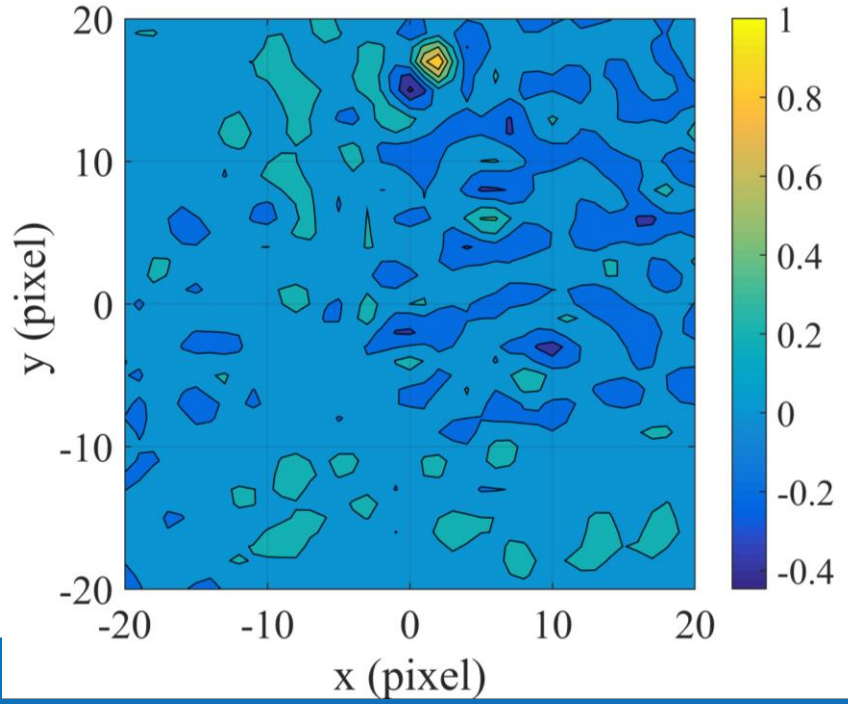


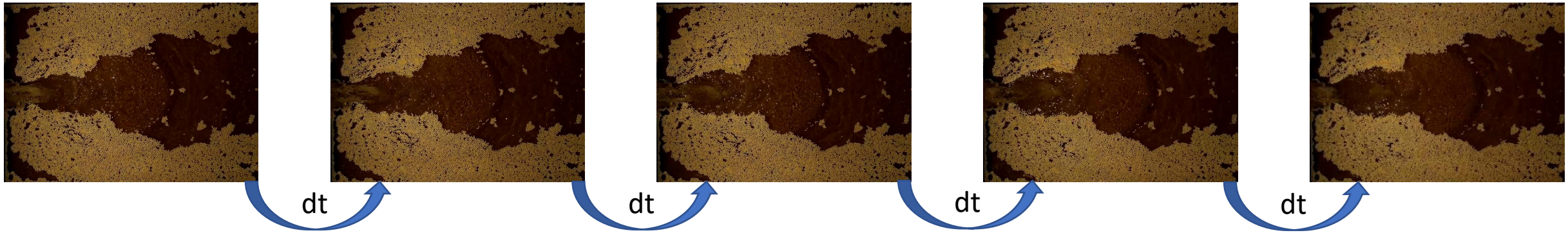


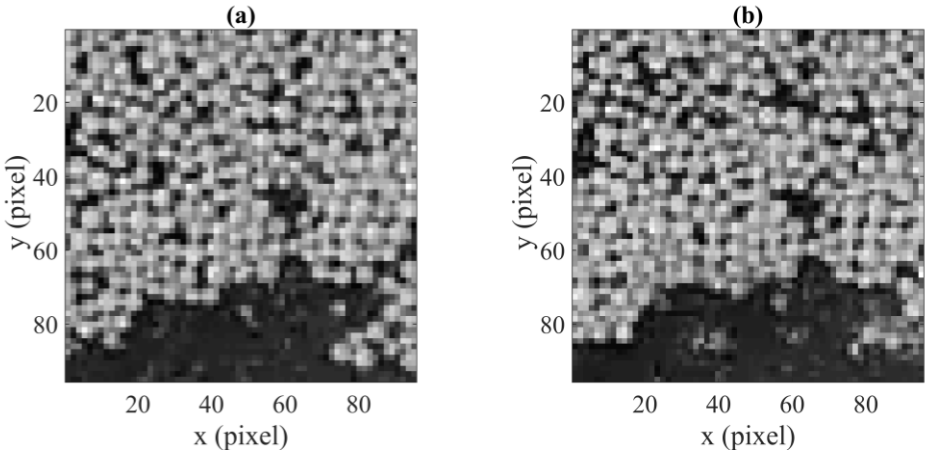


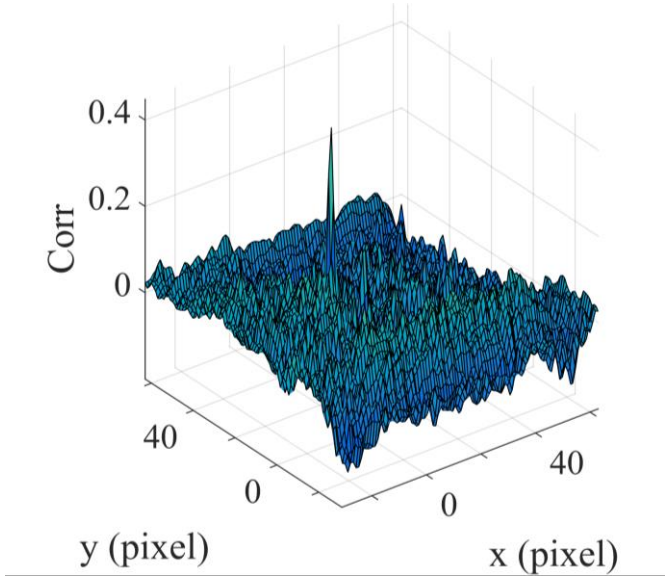


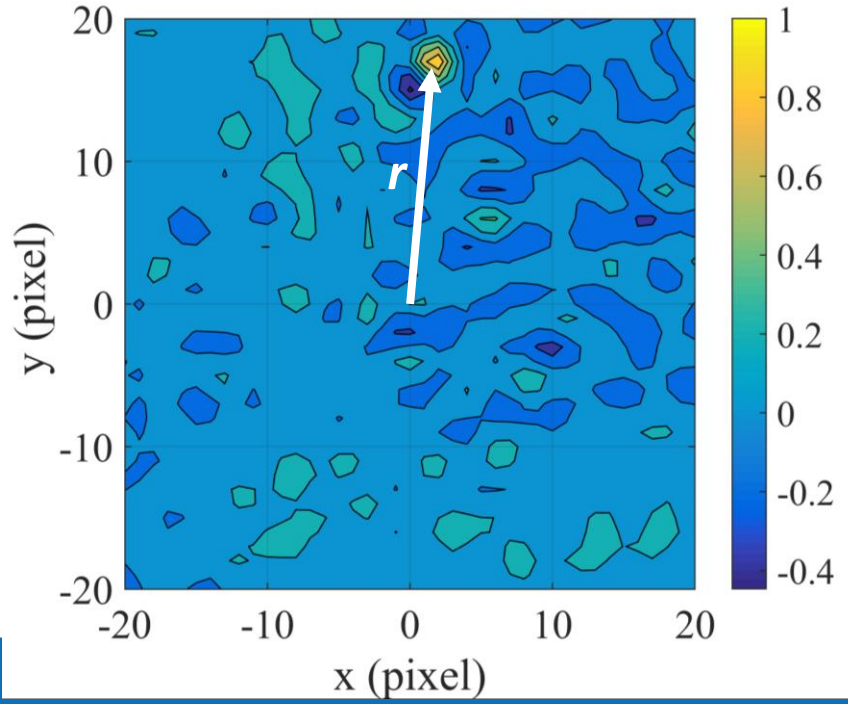
PIV Software: MatPIV [6]
(128 × 128 pix to 32 × 32, 50% overlap)
Seeding: styrofoam spheres (d50 = 3mm)

Velocity measurements: Particle Image Velocimetry









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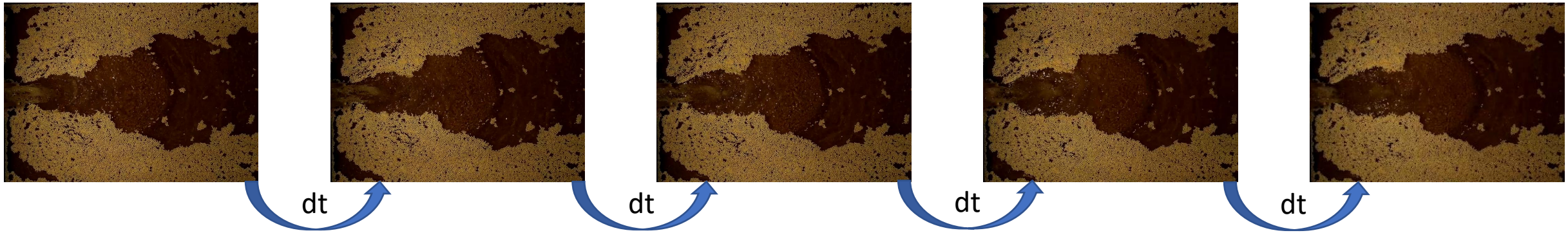

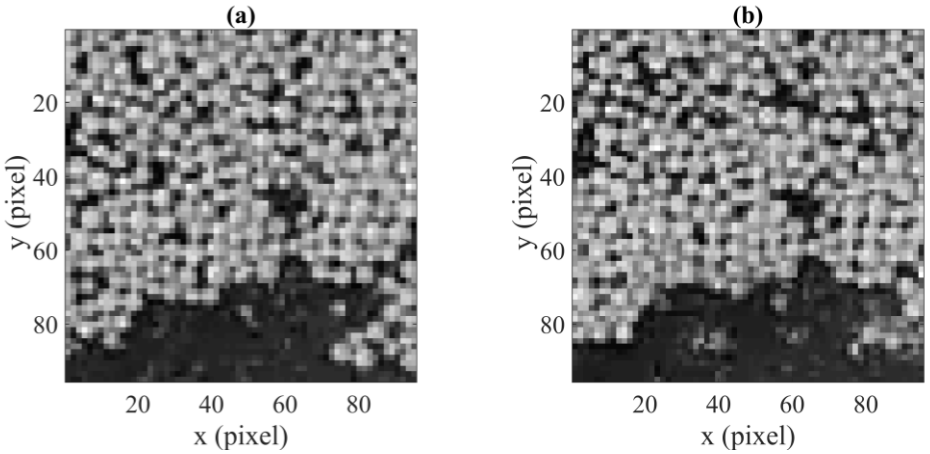

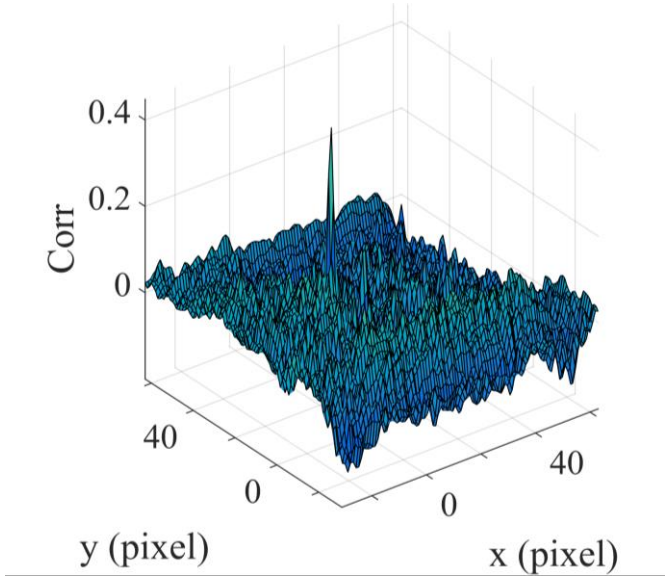

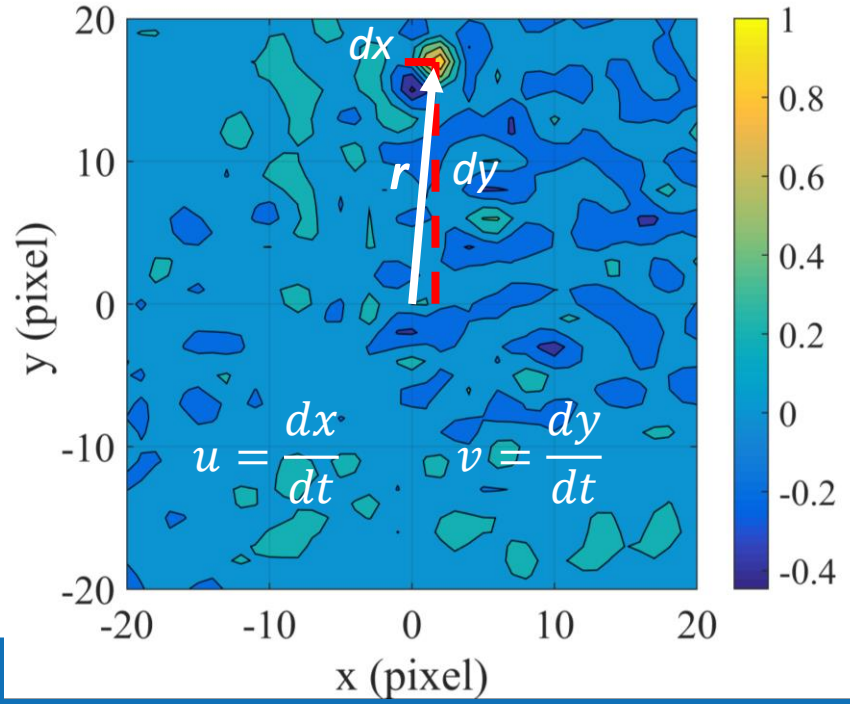

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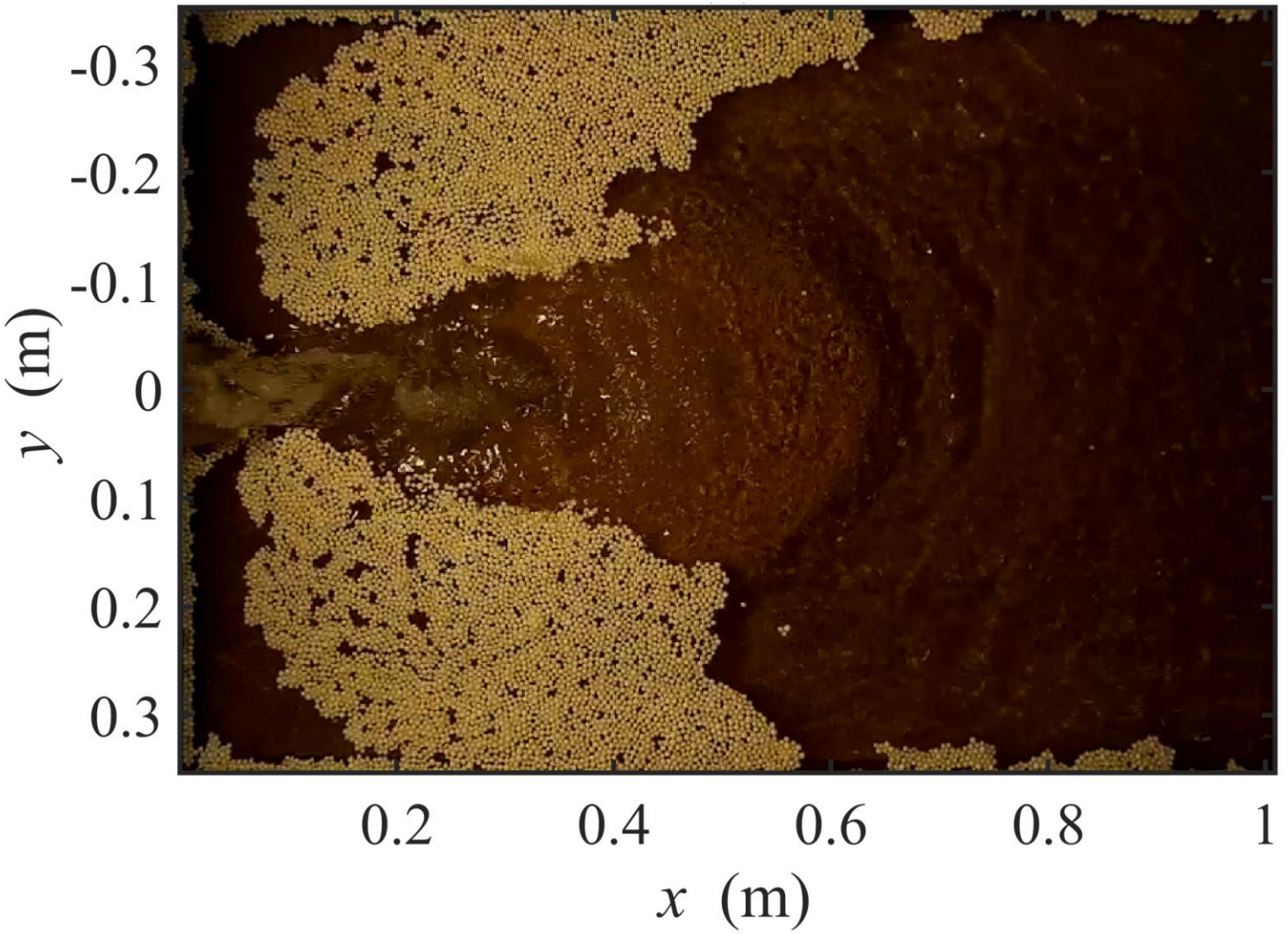
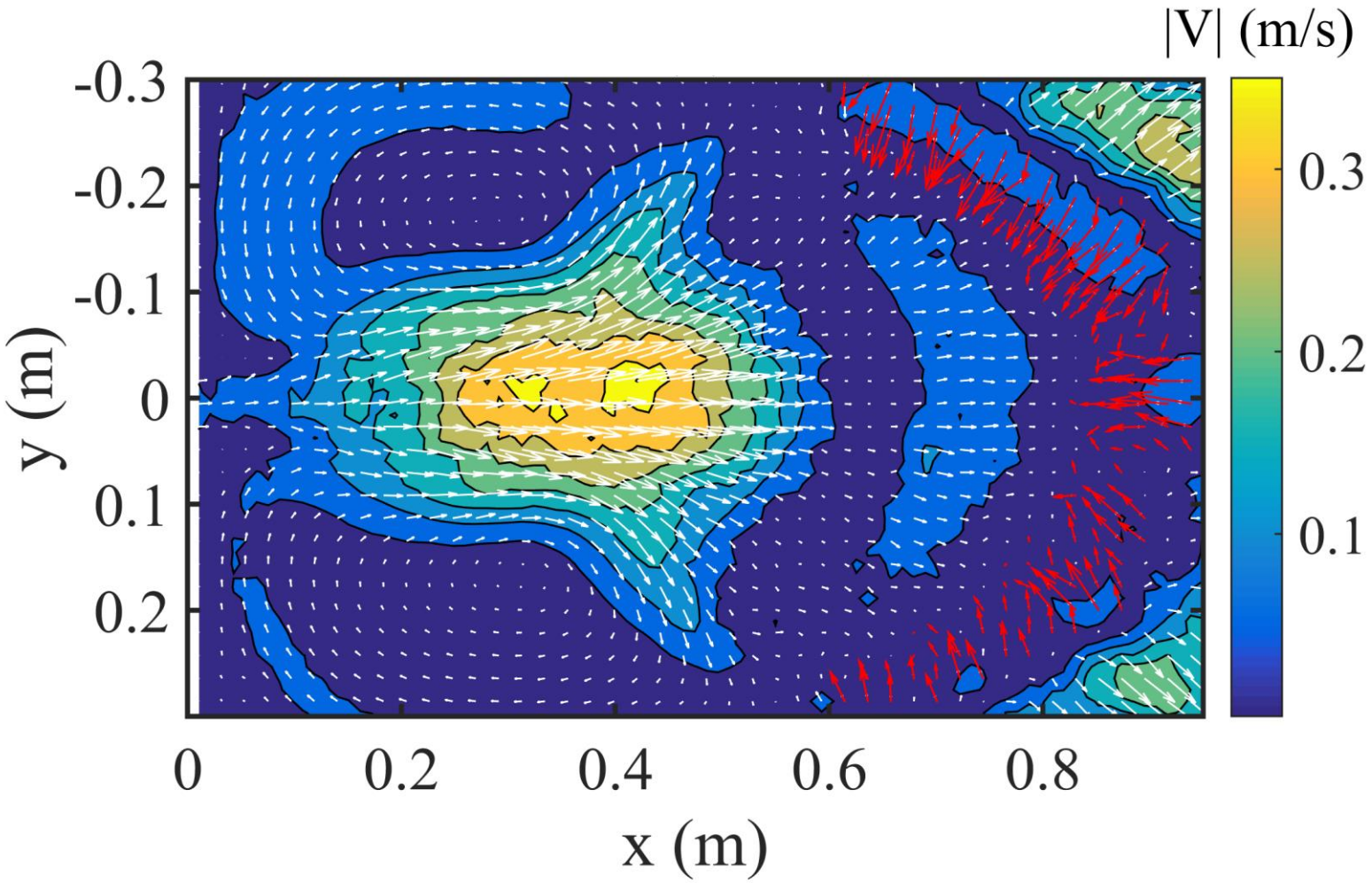
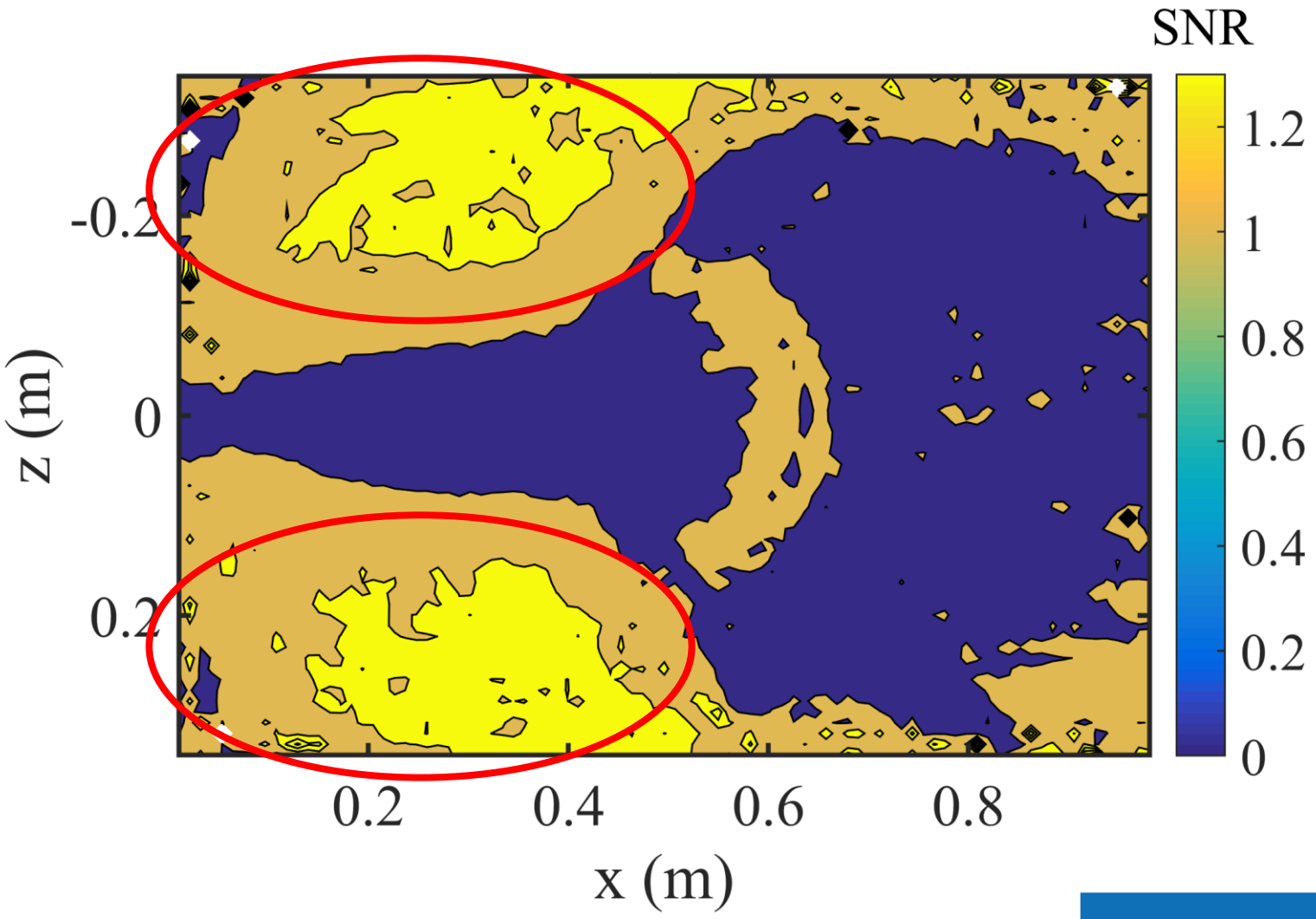


Velocity measurements: Particle Image Velocimetry



Velocity measurements: Particle Image Velocimetry

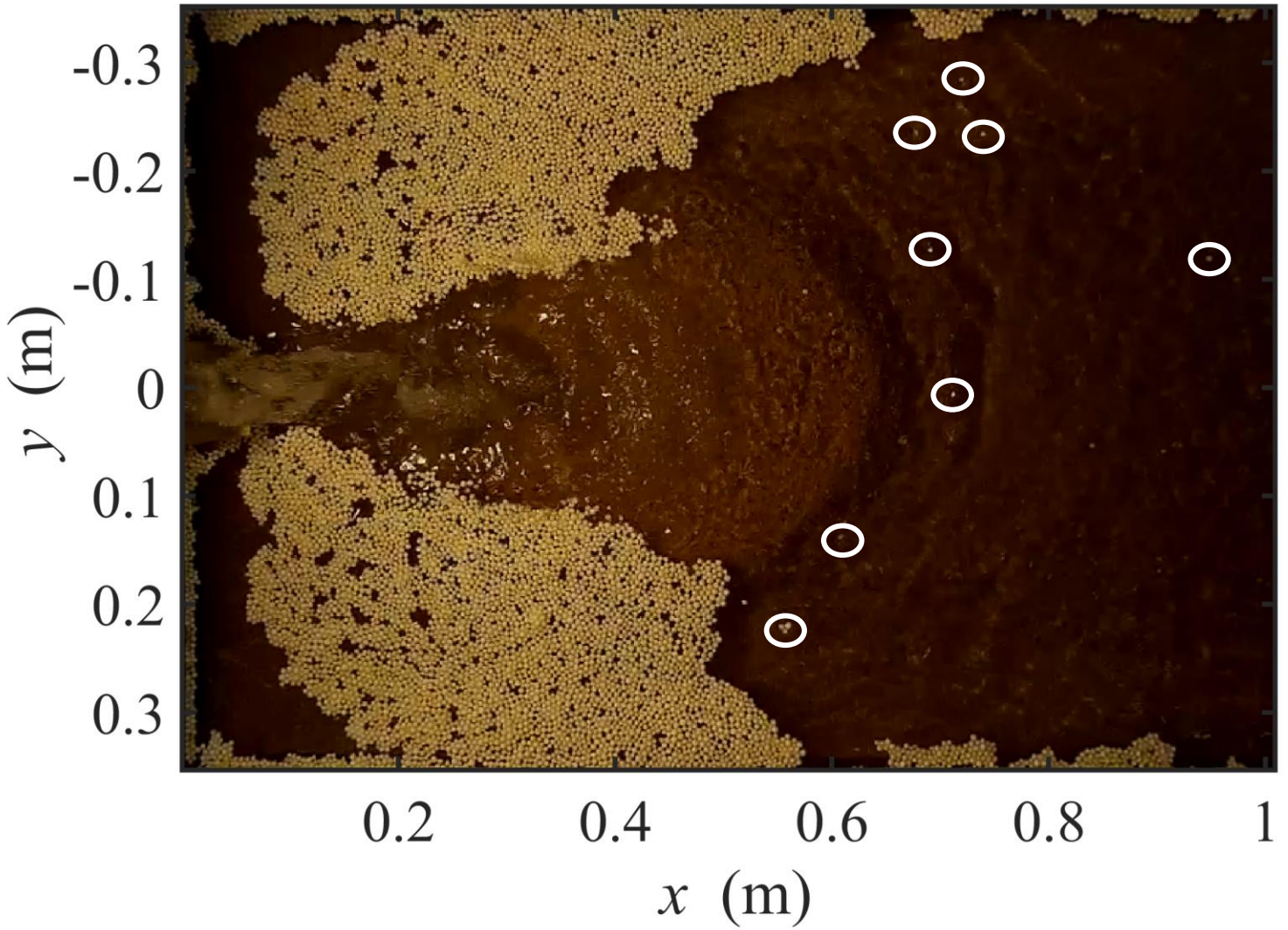


Signal to noise ratio used to filter out PIV values:

If SNR < 1.2 values are disregarded.

Data will be conditionally averaged.

Velocity measurements: Particle Image Velocimetry



Discrete and sparse set of tracers.

Not enough for cross-correlation.

SNR < 1.

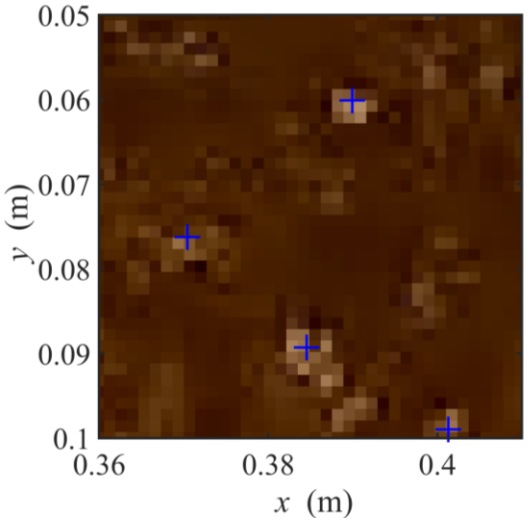
PIV not suitable.

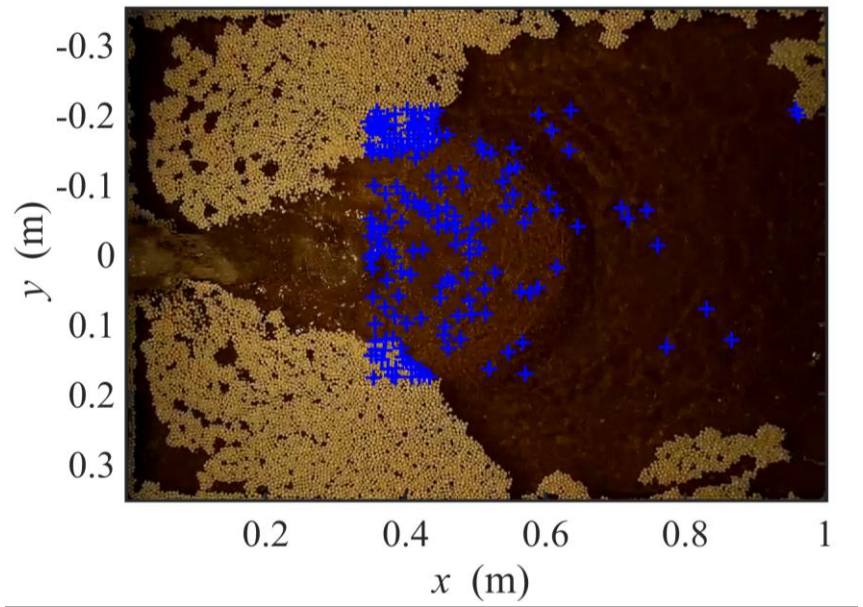
Velocity measurements: Particle Tracking Velocimetry

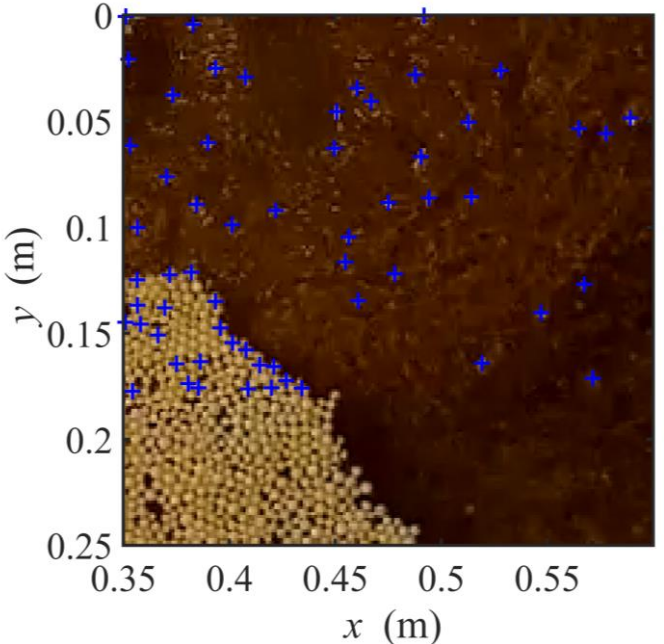
Works well for low tracer densities

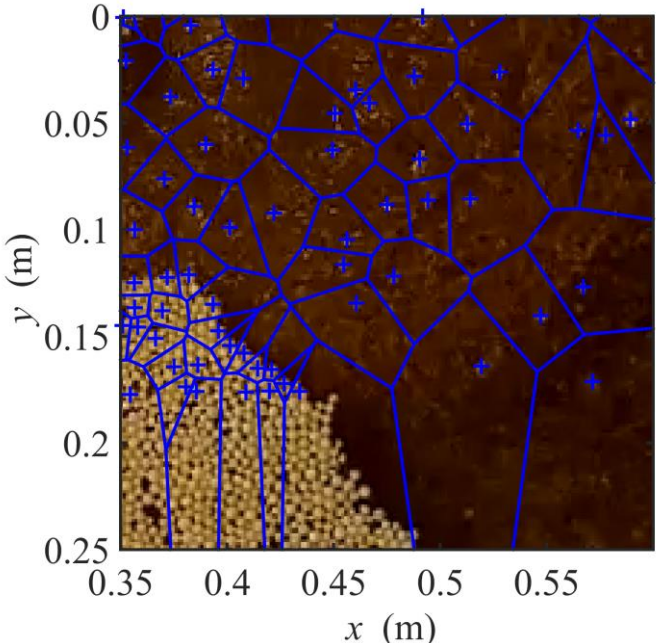
Resolution up to particle's diameter

PTV-Voronoi (Capart et al. 2002)





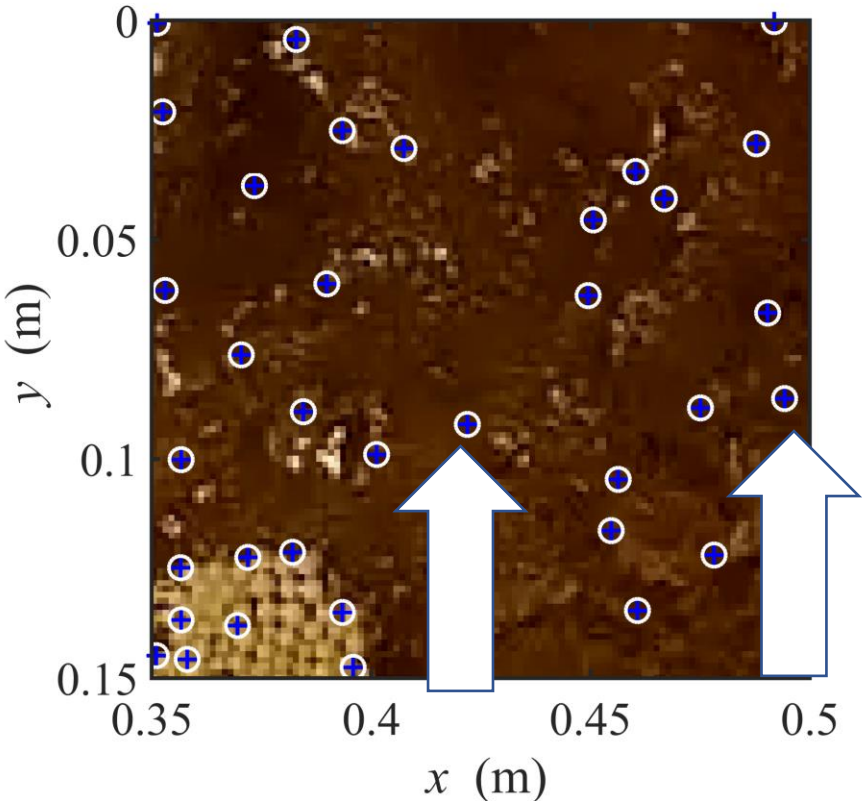


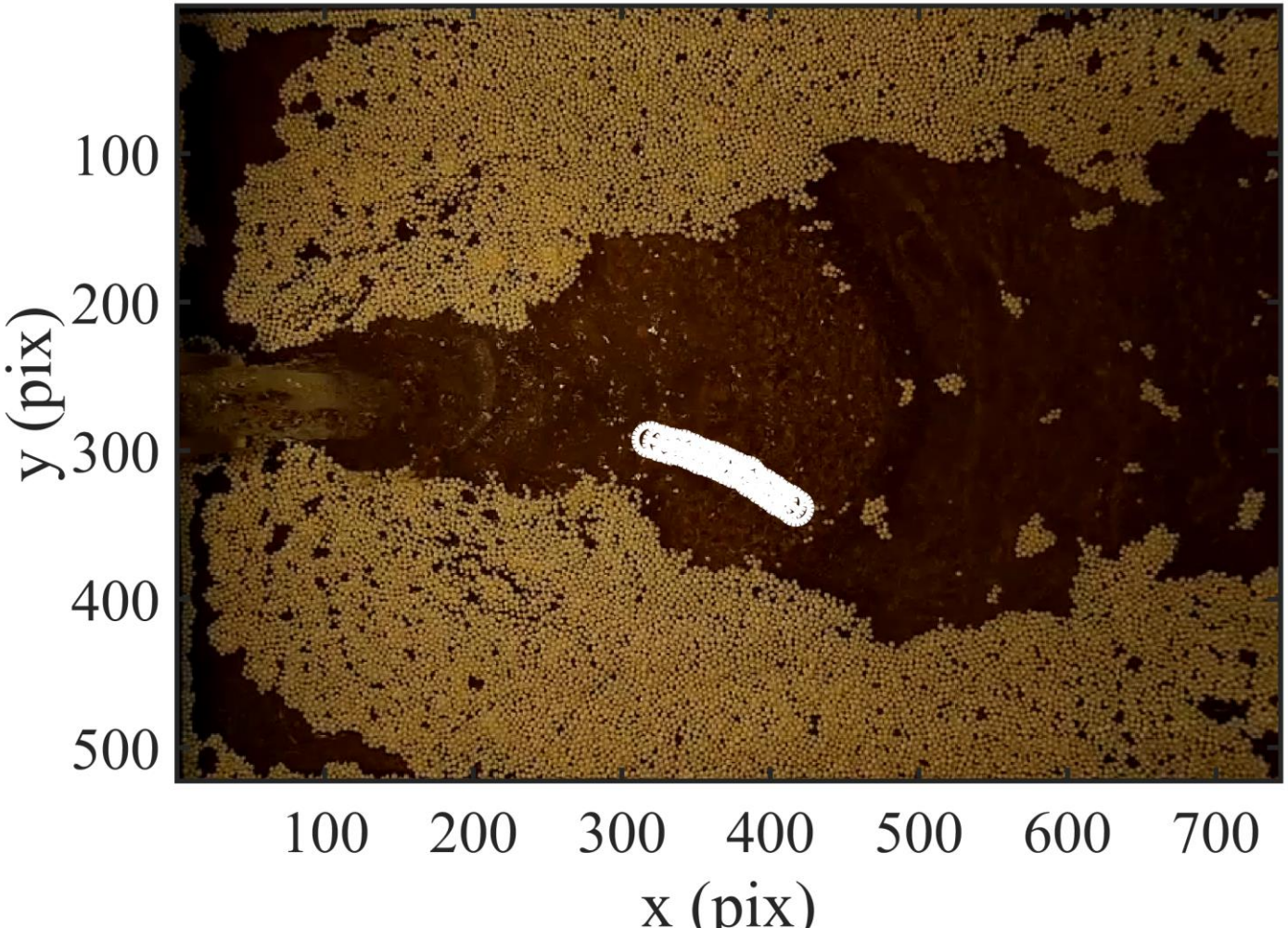


Velocity measurements: Particle Tracking Velocimetry

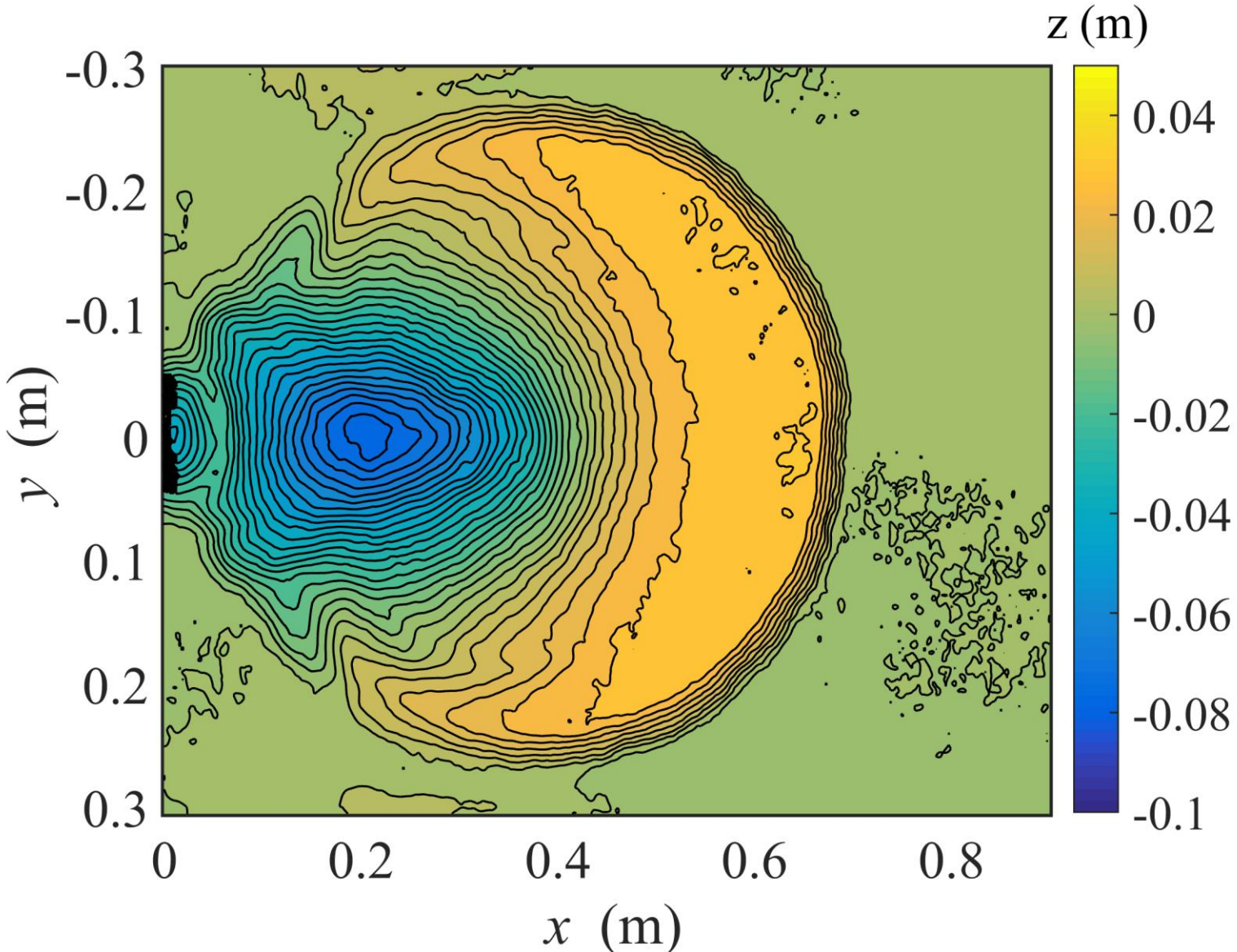
Q: How to deal with the noise?
A: Length of trajectories.

Only particles tracked in (**at least**) 10 images

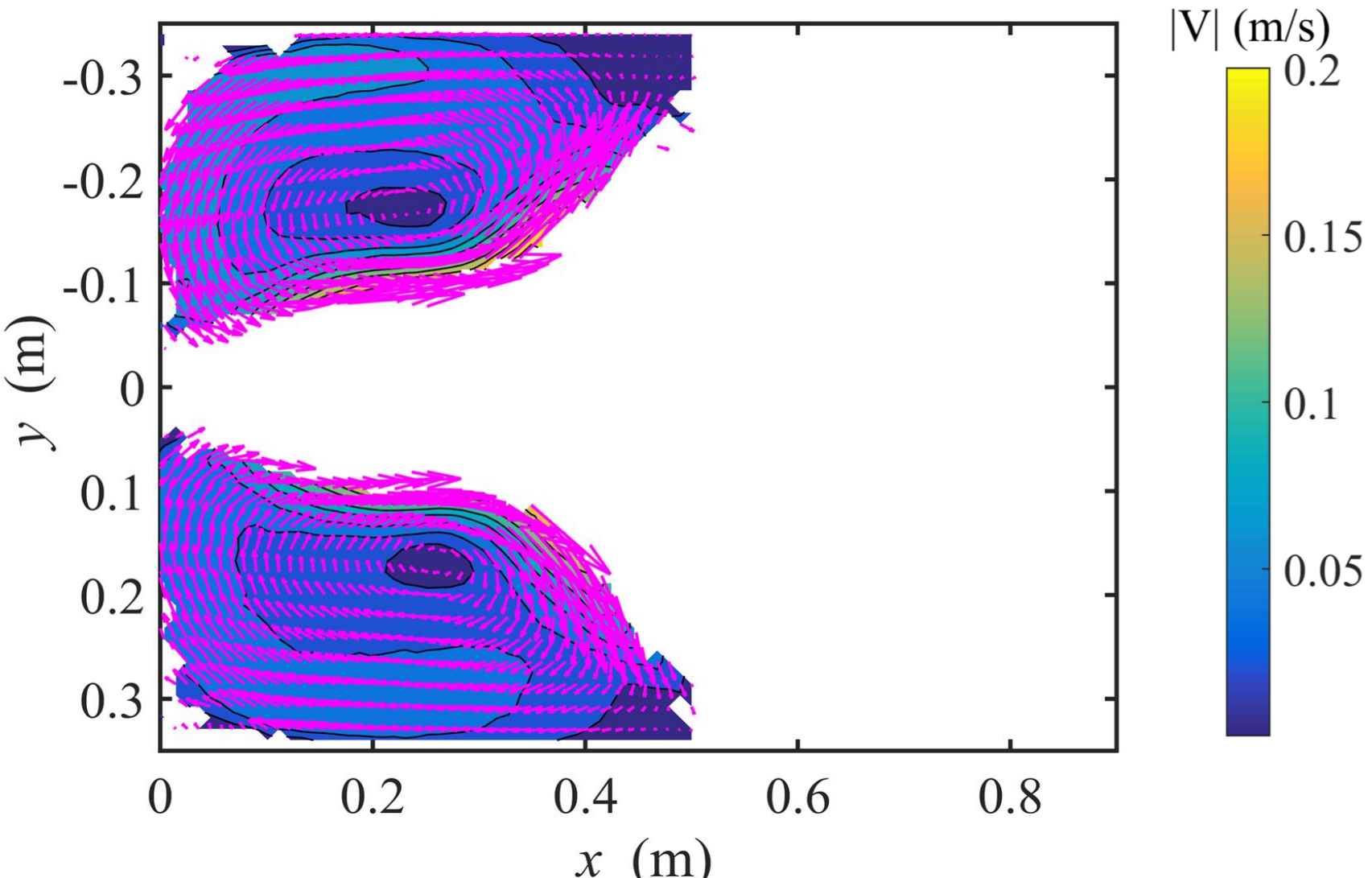




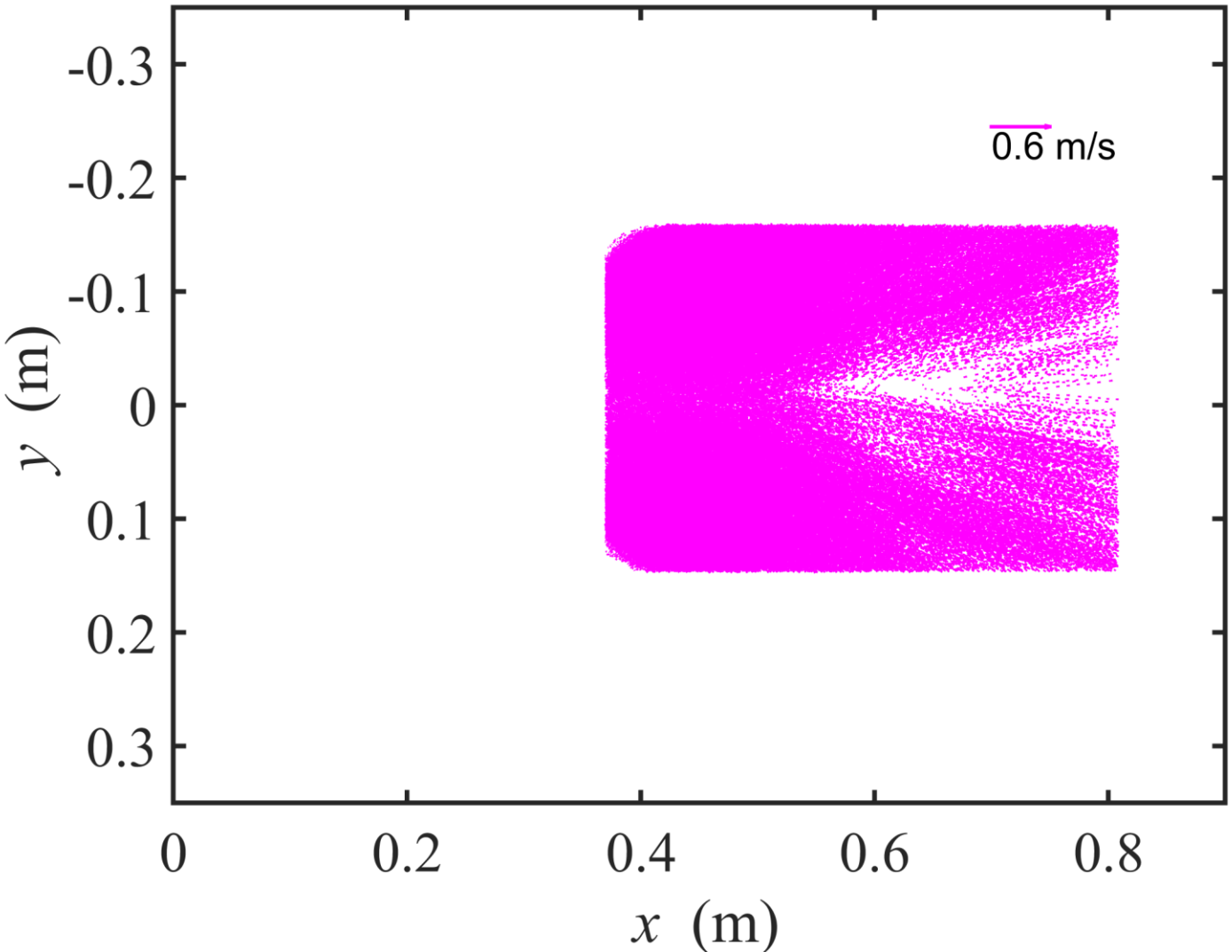
Structure from Motion



Particle Image Velocimetry (PIV)

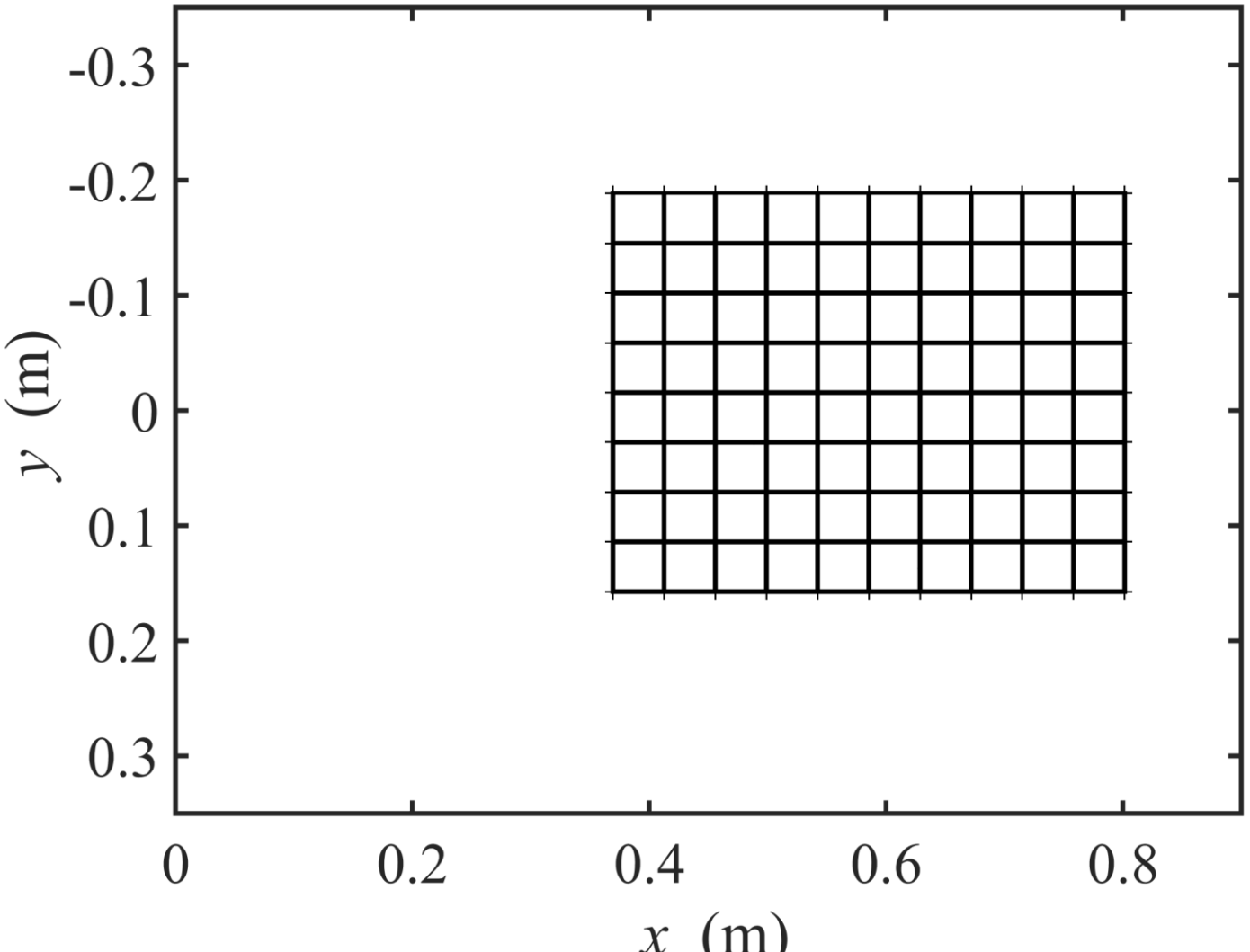


Particle Tracking Velocimetry (PTV)



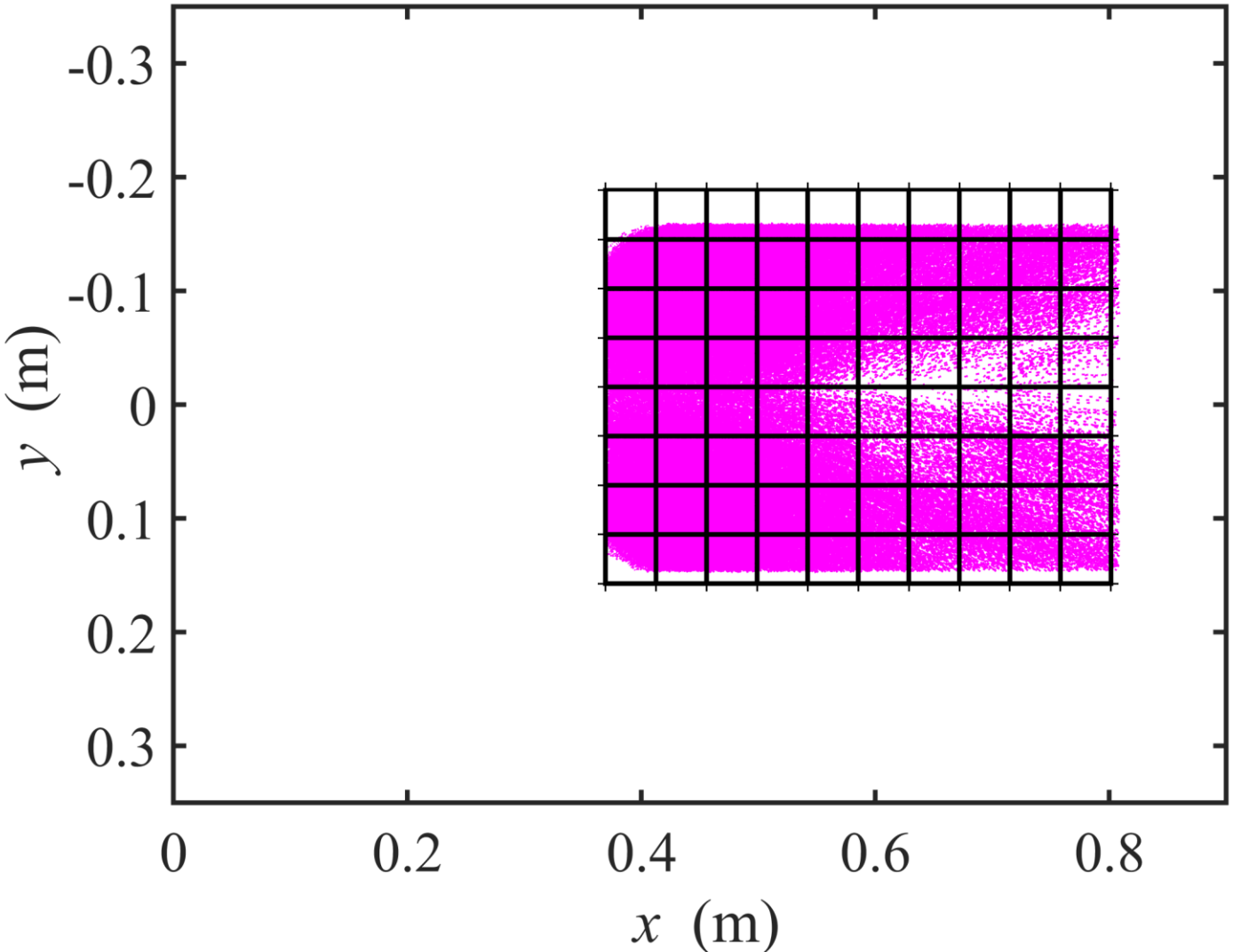
Particle Tracking Velocimetry (PTV) - Binning

From Lagrangian to Eulerian…



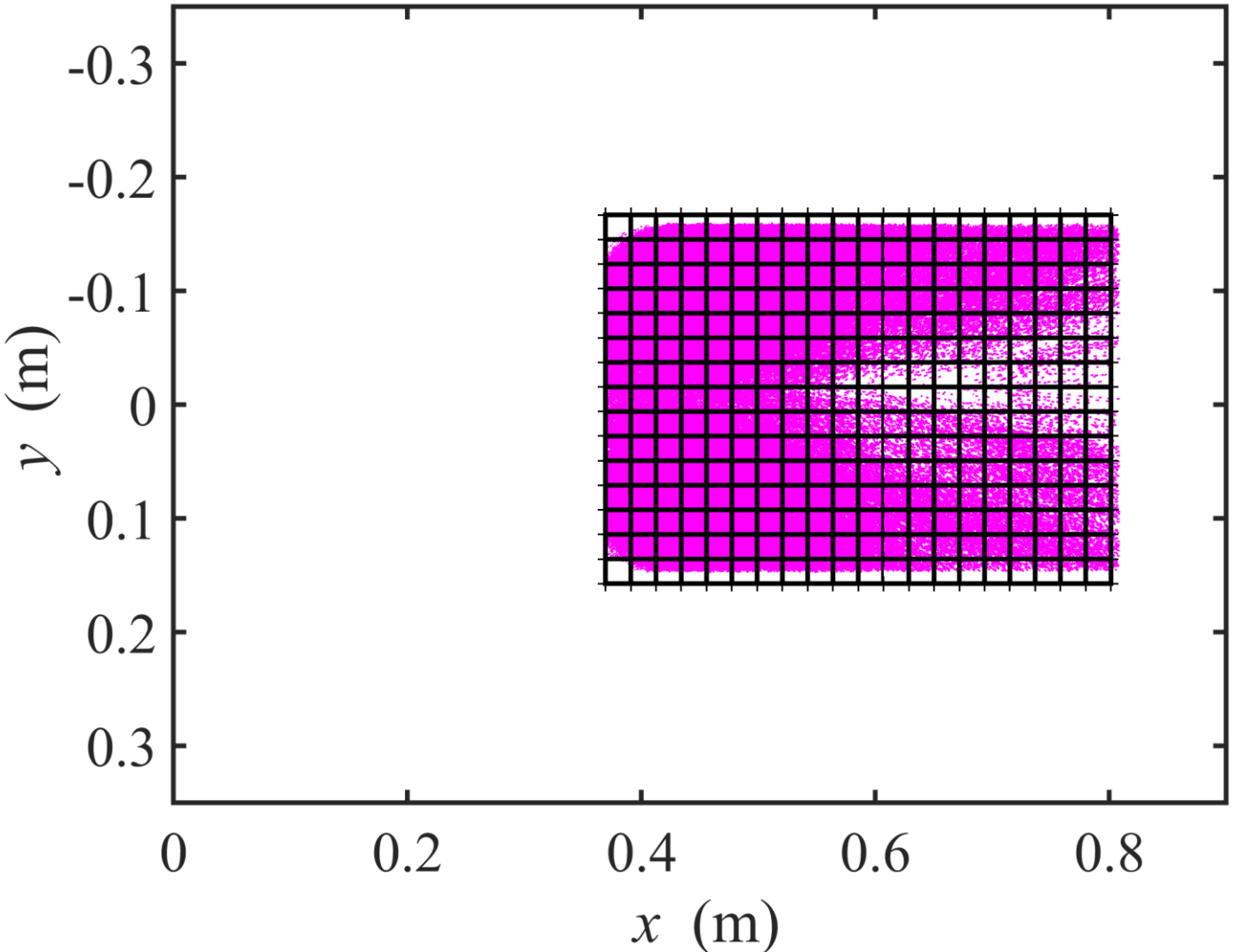
Particle Tracking Velocimetry (PTV) – Binning (32 pix x 32 pix)

From Lagrangian to Eulerian…



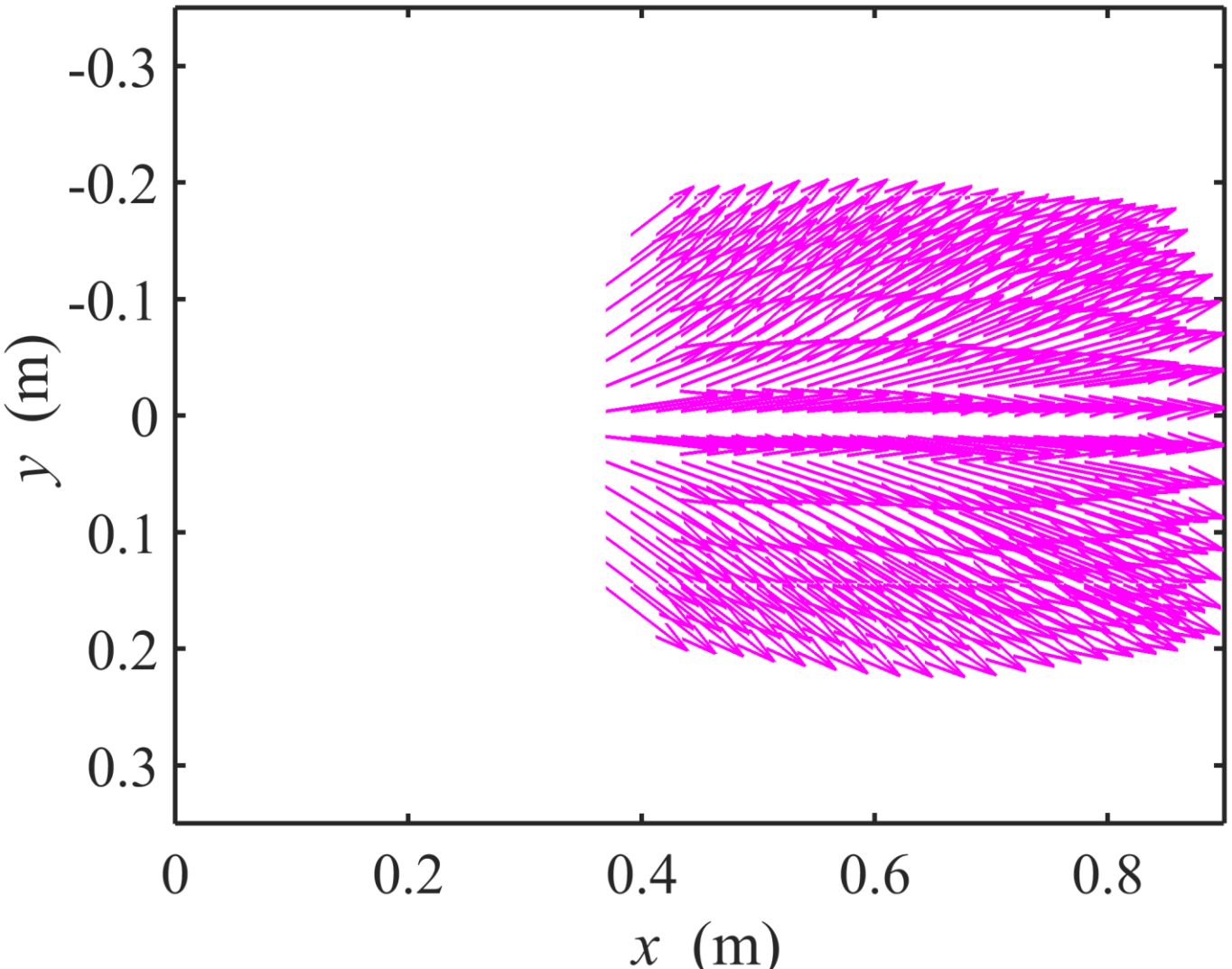
Particle Tracking Velocimetry (PTV) – Binning (16 pix x 16 pix)

From Lagrangian to Eulerian…

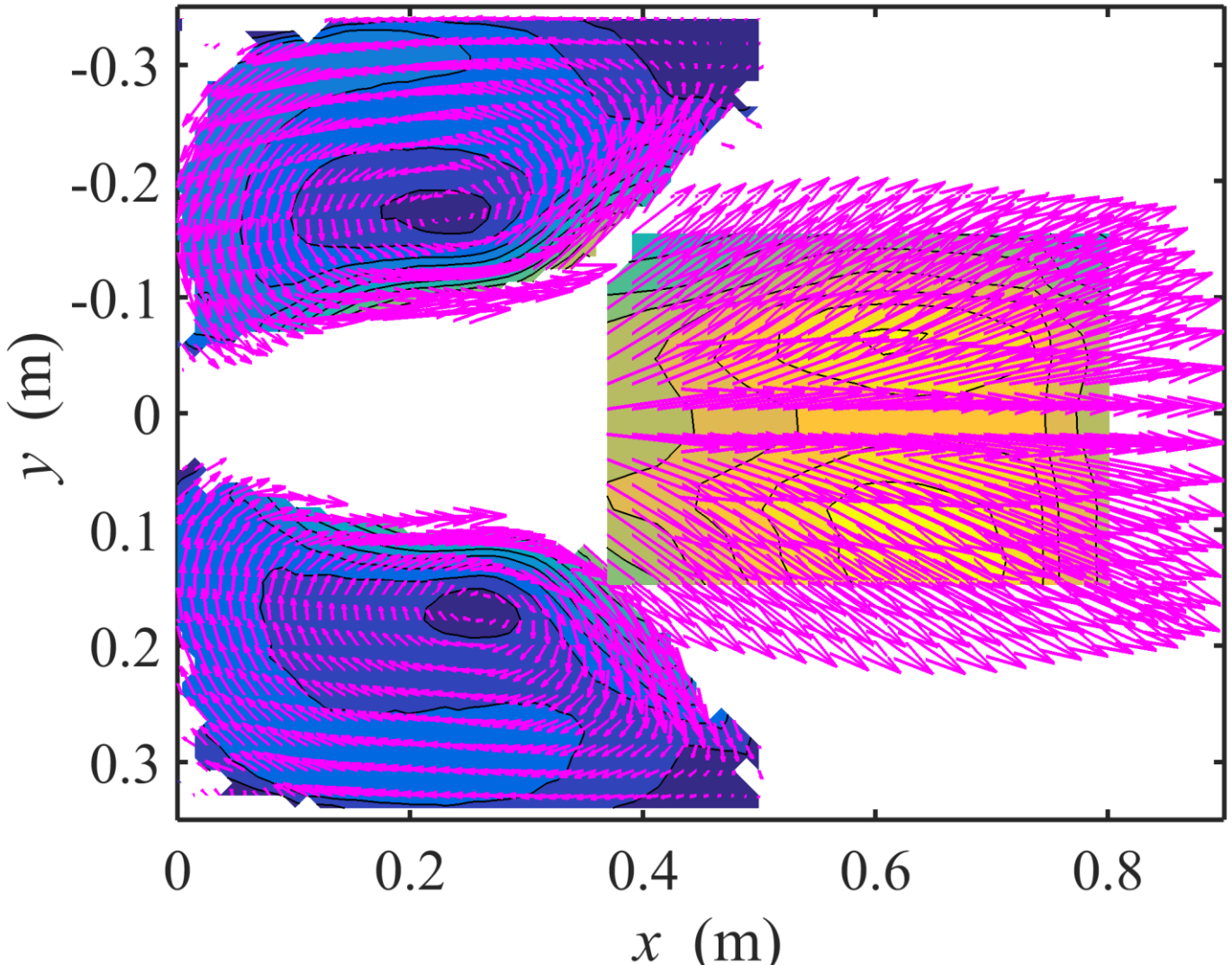


Particle Tracking Velocimetry (PTV) - Binning

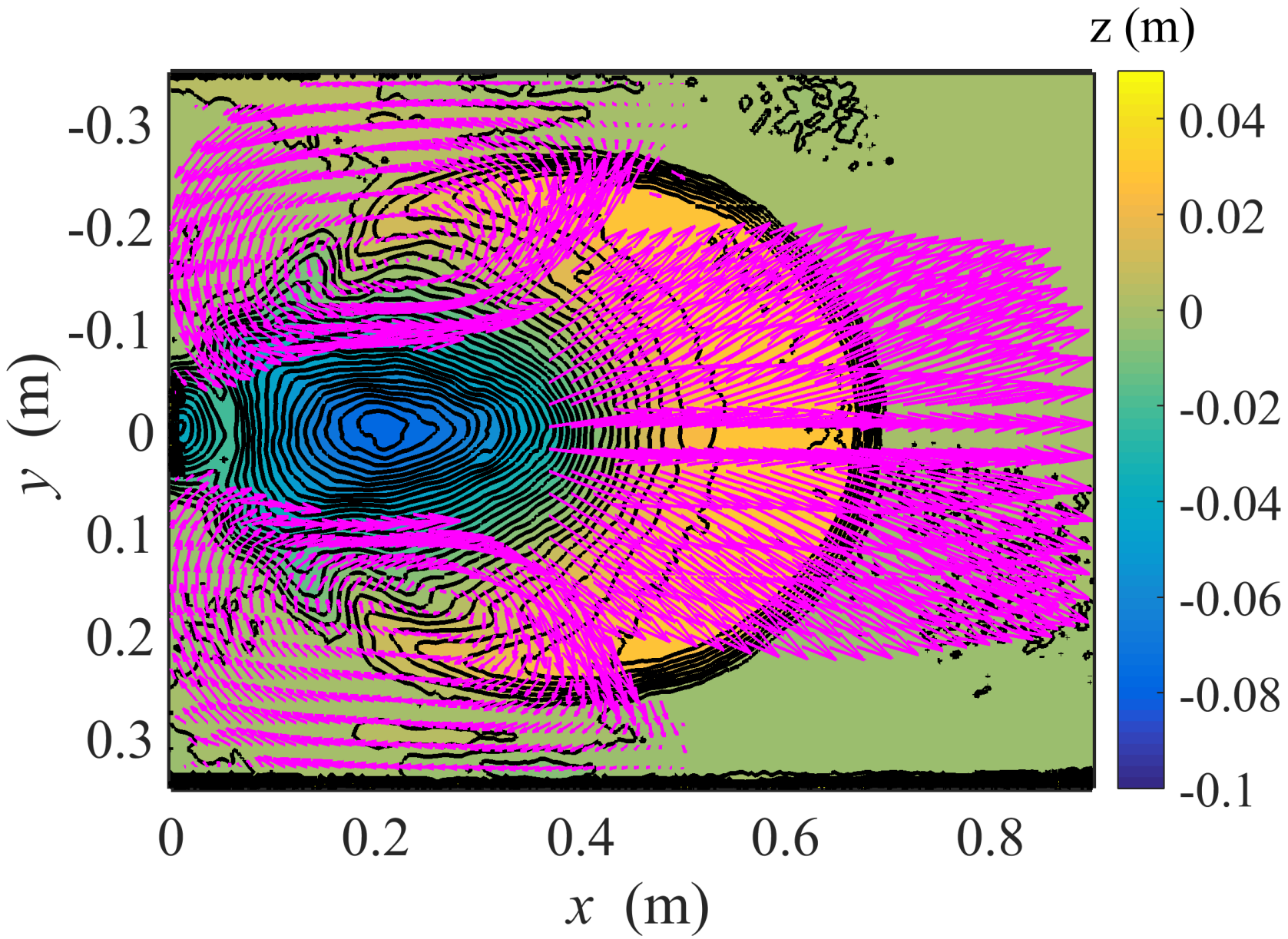
From Lagrangian to Eulerian…



Particle Image Velocimetry & Particle Tracking Velocimetry (Binned)



PIV & PTV & SfM



Conclusions

A 3-prong approach, **SfM, PIV and PTV**, was made to the analysis of the effect of a jet impinging on a stilling basin with a loose bed made of sand at equilibrium.

SfM allowed to characterize the 3D bed and extract the meaningful variables of the bed geometry, namely **maximum depth**, **maximum height** of the deposition bar and **scour hole volume**.

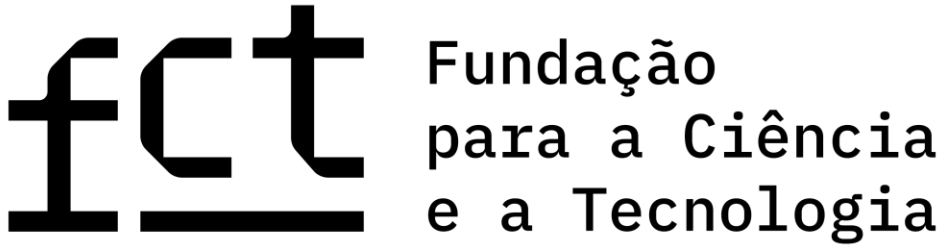
On the other hand, PIV and PTV allowed determining the surface velocity field: **PIV** was used in the regions where the **seeding concentration was high**, and **PTV** was used in the regions where the **seeding concentration was low**.

PTV allowed also to determine the trajectories of the seeding above the deposition bar, allowing to demonstrate the **radial dispersion** characteristic of the flow.

Future analysis should be focus on the identified recirculation regions, using tools such as the FFT to compute the oscillation frequency of the vortexes.

Acknowledgments

The velocimetry processing functions, PIV and PTV, were developed in the scope of the project DikesFPro, PTDC/ECI-EGC/7739/2020 supported by Fundação para a Ciência e a Tecnologia, Portugal.



[1] L. Sá Machado, M. M. C. L. Lima, R. Aleixo & E. Carvalho (2020) Effect of the ski jump bucket angle on the scour hole downstream of a converging stepped spillway, International Journal of River Basin Management, 18:3, 383-394, DOI: 10.1080/15715124.2019.1586717

[2] A. Meydenbauer (1867) Die Photogrammetrie. In: Wochenblatt des Architektenvereins zu Berlin Jg. 1, Nr. 49, S. 471–472

[3] K. Konecny (2002). Geoinformation: Remote Sensing, Photogrammetry and Geographic Information Systems, CRC Press

[4] W. Linder (2006) Digital Photogrammetry – A practical course, Springer, Berlin Heidelberg

[5] R. Santos, E. Carvalho, M. M. Lima & Rui Aleixo (2021) Time evolution of the scour induced by a ski jump jet, Journal of Applied Water Engineering and Research, DOI: 10.1080/23249676.2021.1919226

[6] Sveen https://www.mn.uio.no/math/english/people/aca/jks/matpiv/

[7] H. Capart, D.L. Young, Y. Zech (2002) Voronoï imaging methods for the measurement of granular flows. Exp Fluids 32:121–135

The end.
Thank you for your attention.

Koniec.
Dziękuję za uwagę.