DualSPHysics simulation of a vertical slot fishway

Gorazd NOVAK, Dušan ŽAGAR, Matjaž ČETINA

University of Ljubljana, Slovenia

Martin BOMBAČ

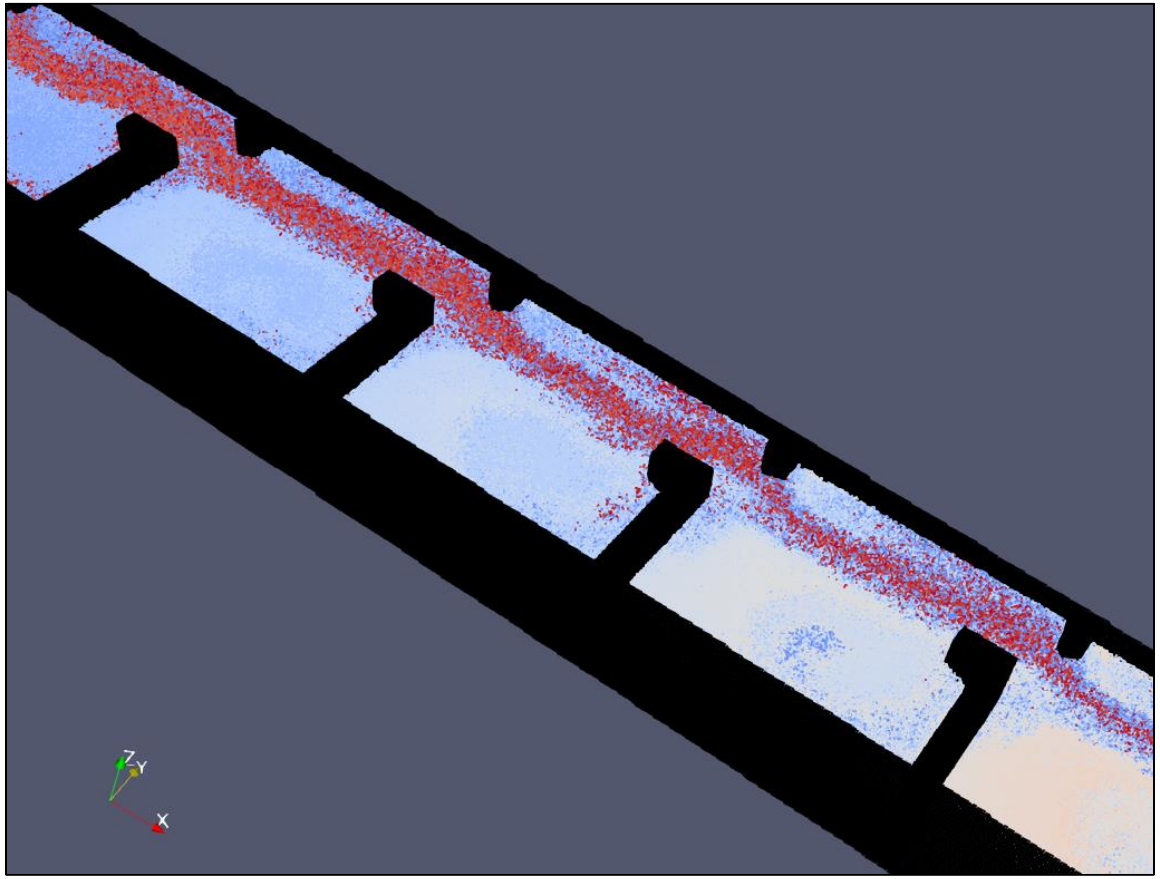
Institute for hydraulic research, Ljubljana, Slovenia

gorazd.novak@fgg.uni-lj.si

Contents

- Vertical slot fishway
- Field measurements
- Depth averaged 2D model
- Dual SPHysics v4.2 model

  - input
  - discussion of results
  - further work



Vertical slot fishway

- Fishways have a great ecological importanece, as they bridge the interruption of fish migration routes, caused by HPP dams
- Types: weir, Denil, culvert, VSF
- VSF: linear relation $h(Q)$

Field measurements

- HPP Arto – Blanca, Sava, Slovenia
- Constant conditions: Q = 1.0 m^3/s; h = 1.3 m; Δh = 5 cm between pools;

$$S_{water} = 5 \text{ cm} / 300 \text{ cm} = 0.0167$$

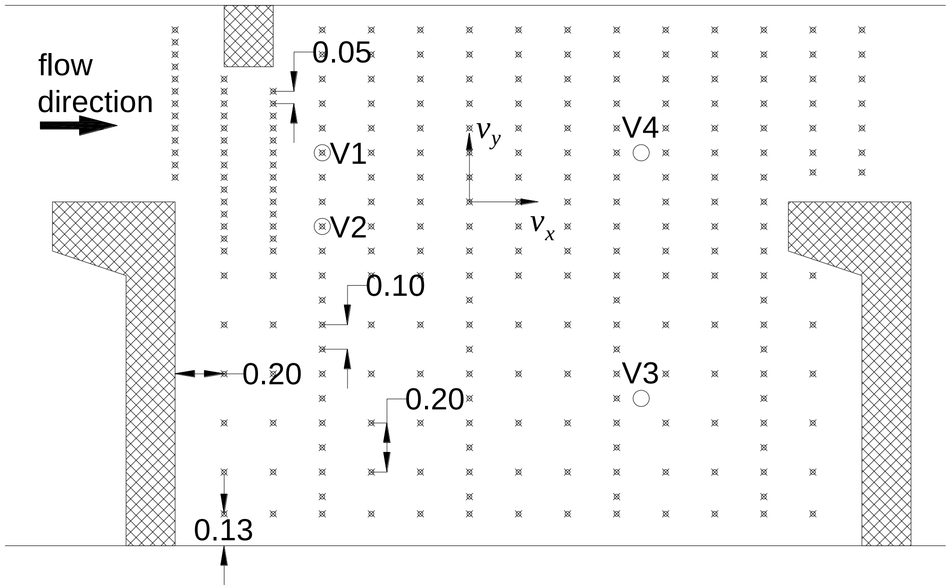
- Measurements:

- leveling → elevation (water surface, bed)
- ADV probe → velocity components

u, v, w in 4 representative verticals (V1 … V4)

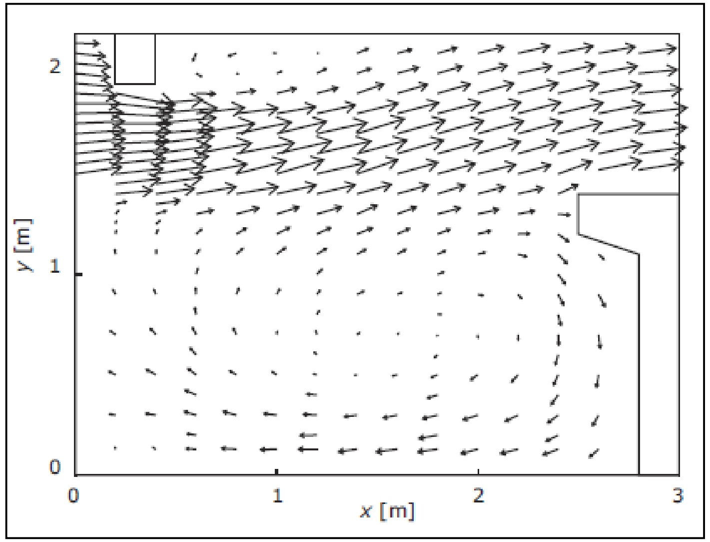
→ confirmed: flow indeed mostly 2D

→ → u, v in 250 points at z/h = 0.4 (z = 0.5 m)



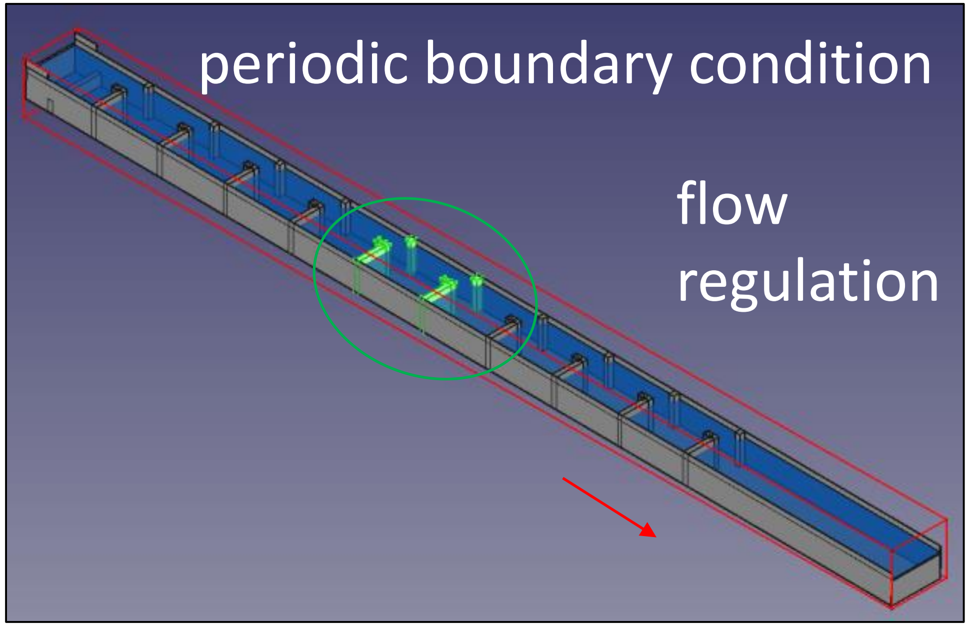
Depth-averaged 2D model PCFLOW2D

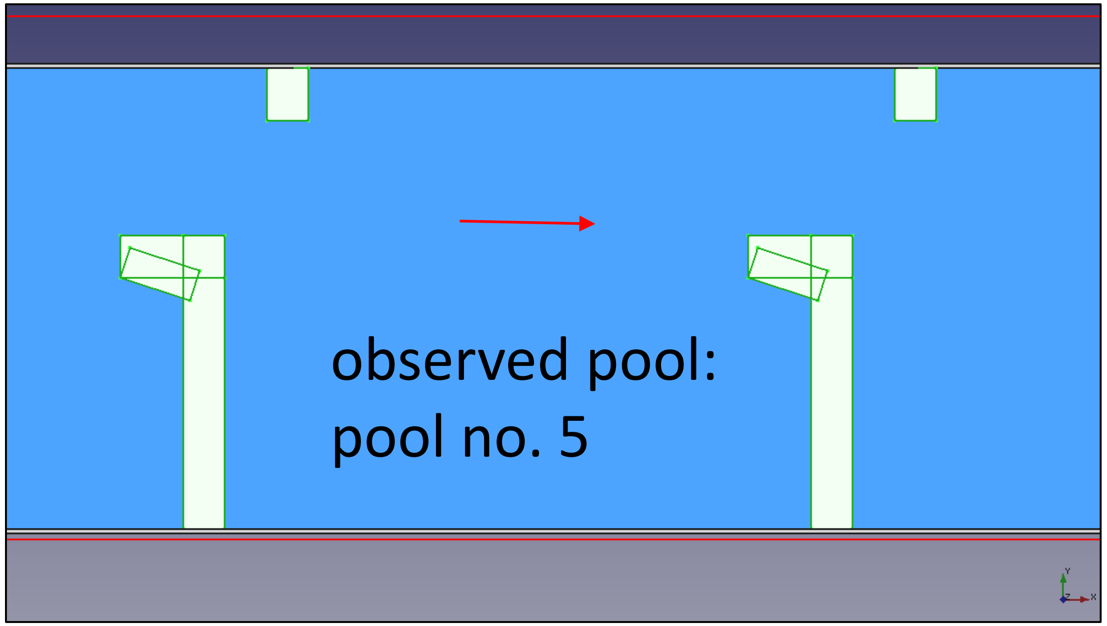
- Depth-averaged shallow water equations,
  coupled with depth-averaged $k - \varepsilon$ turbulence model
- Mesh: Δx = 1 cm, Δy = 2 cm (to minimise numerical diffusion)
- Time step: Δt = 0.1 s (to ensure numerical stability and convergence)
- Simulated: 1 h in nature
- Computational time: several days



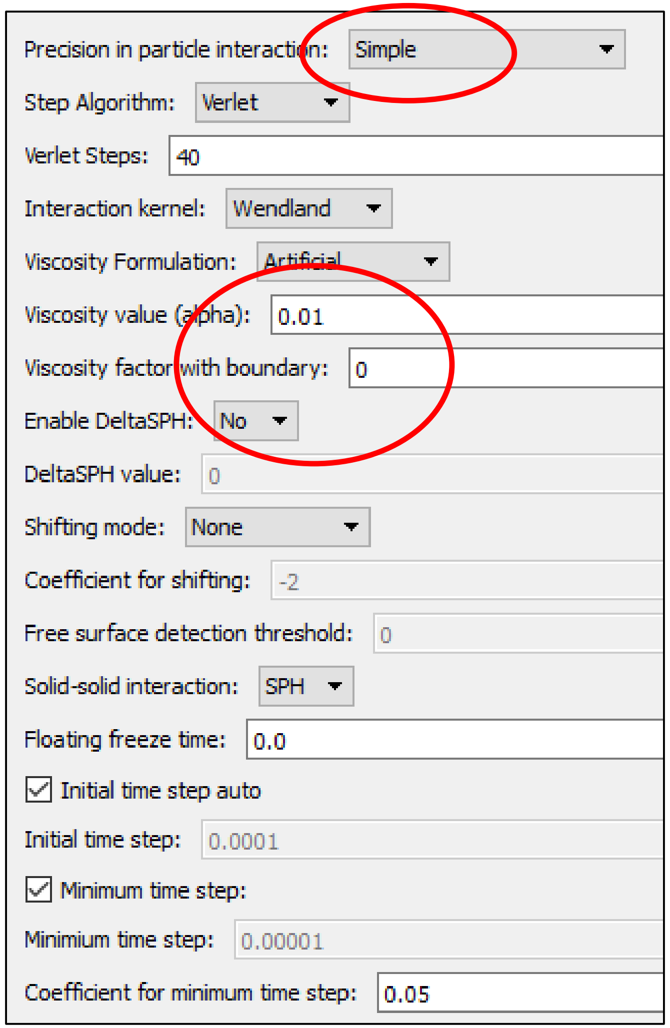
Dual SPHysics v4.2 model - geometry

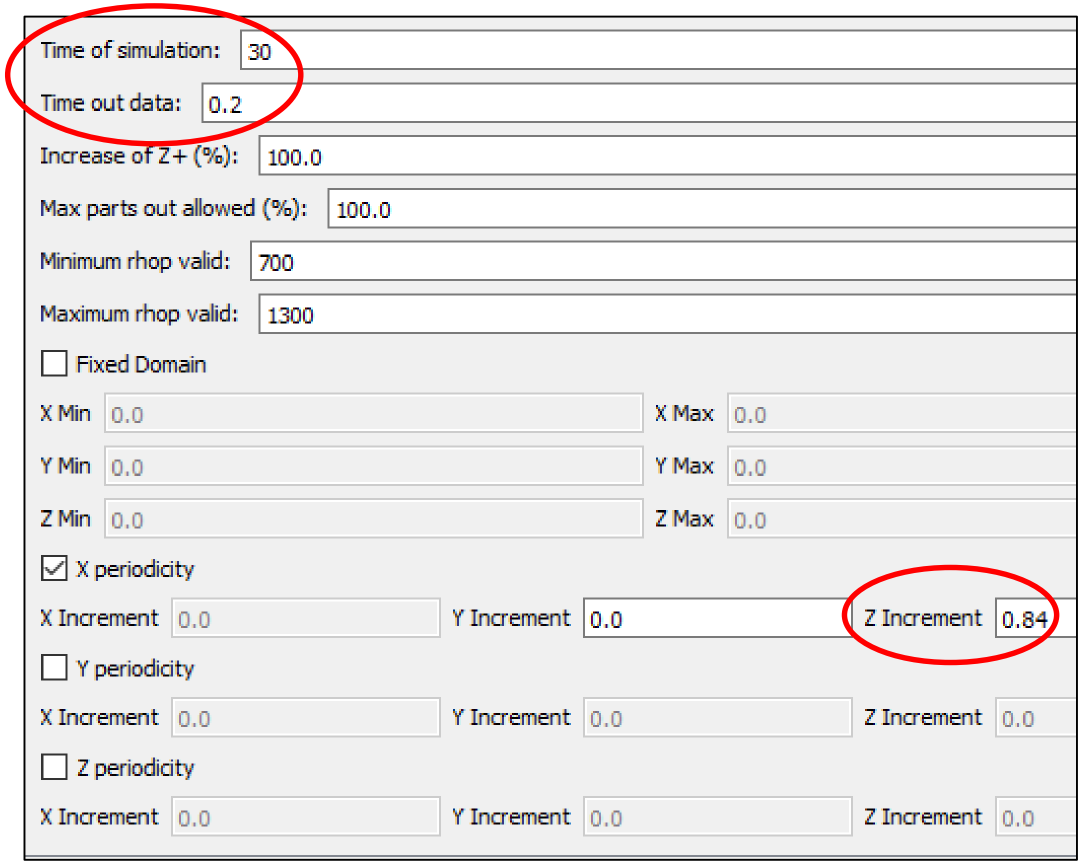
- Inlet + 9 pools + outlet = 39.5 x 2.2 x 1.5 m, S_{bed} = 0.0167
- Blocks, fill mode: full; object order: F0, B0,… B47
- *dp* = 2 cm → GenCase: 15.1 M particles





Constants and execution parameters

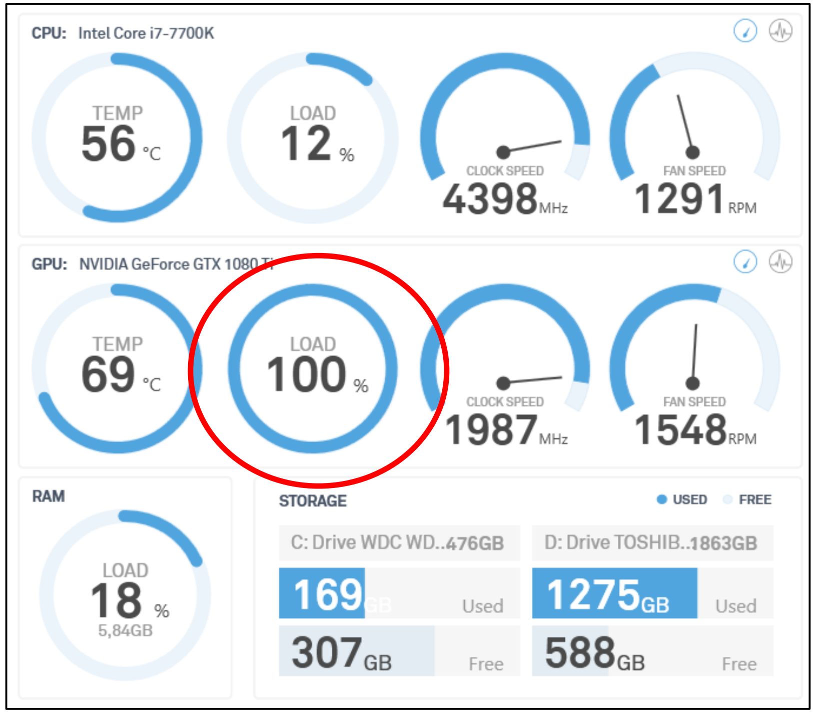




Constants: default values

GPU run

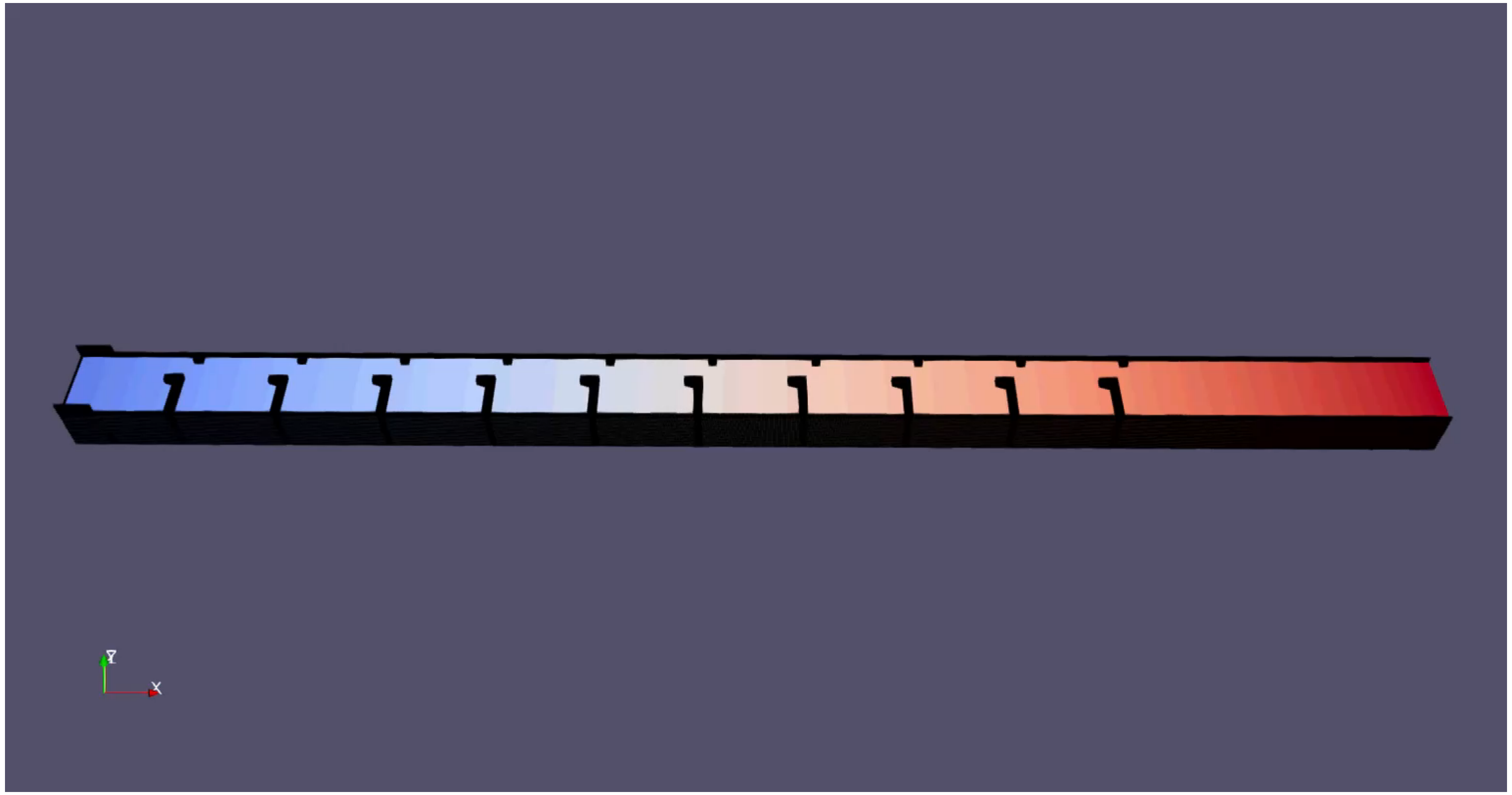
- Nvidia GeForce GTX 1080
- Total RunTime: 23.3 h



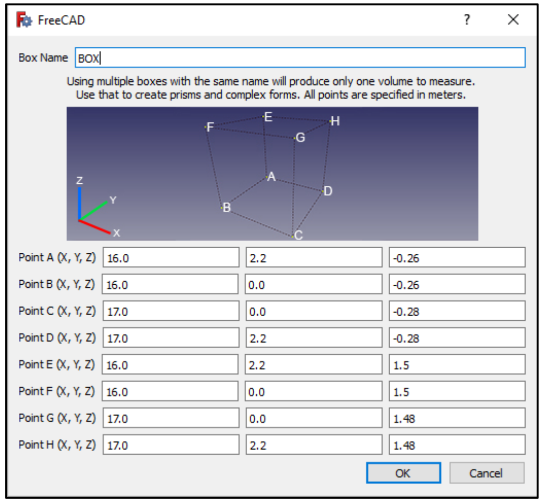

```
DualSPHysics4 v4.2.058 (04-06-2018)
====================================
[Select CUDA Device]
[CUDA Capable device(s)]
  Detected 1 CUDA Capable device(s)
  CUDA Driver Version / Runtime Version: 9.2 / 9.2

Device 0: "GeForce GTX 1080 Ti"
  CUDA Capability Major....: 6.1
  Global memory............: 11264 MBytes
  CUDA Cores...............: 3584 (28 Multiprocessors, 128 CUDA Cores/MP)
  GPU Max Clock rate.......: 1721 MHz (1.72 GHz)
  Memory Clock rate........: 5505 Mhz
  Memory Bus Width.........: 352-bit
  L2 Cache Size............: 2816 KBytes
  Constant memory..........: 64 KBytes
  Shared memory per block..: 48 KBytes
  Registers per block......: 65536
  Maximum threads per MP...: 2048
  Maximum threads per block: 1024
  Concurrent copy and kernel execution....: Yes with 2 copy engine(s)
  Run time limit on kernels...............: Yes
  Integrated GPU sharing Host Memory......: No
  Support host page-locked memory mapping.: Yes
  Device has ECC support..................: Disabled
  CUDA Device Driver Mode (TCC or WDDM)...: WDDM (Windows Display Driver Model)
  Device supports Unified Addressing (UVA): Yes
  Device PCI (Domain / Bus / location)....: 0 / 1 / 0
  Device supports P2P and RDMA............: No

[GPU Hardware]
Device default: 0  "GeForce GTX 1080 Ti"
Compute capability: 6.1
Memory global: 11264 MB
Memory shared: 49152 Bytes
[Initialising JSphGpuSingle  14-09-2018 11:13:08]
ProgramFile=".../dualsphysics/EXECS/DualSPHysics4.2_win64.exe"
ExecutionDir=".../FreeCAD/Mod/DesignSPHysics"
XmlFile=".../Steza_20/Steza_20_out/Steza_20.xml"
OutputDir=".../Steza_20/Steza_20/Steza_20_out"
OutputDataDir=".../Steza_20/Steza_20/Steza_20_out"
**Basic case configuration is loaded
**Special case configuration is loaded
Loading initial state of particles...
Loaded particles: 15092273
MapRealPos(border)=(-5.20417e-18,-0.0117321,-0.691732)-(39.52,2.23173,1.79173)
MapRealPos(final)=(-5.20417e-18,-0.0117321,-0.691732)-(39.52,2.23173,4.2752)
**Initial state of particles is loaded
**3D-Simulation parameters:
CaseName="Steza_20"
RunName="Steza_20"
PosDouble="0: Uses and stores in single precision"
```

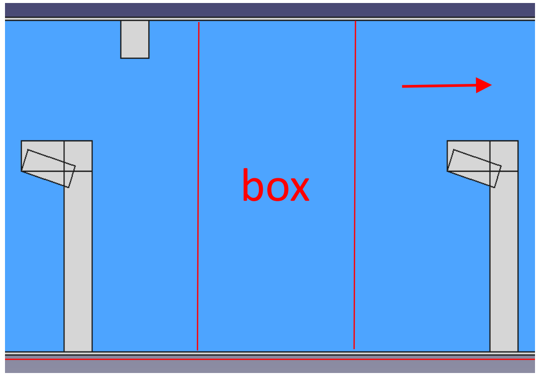
Visualization

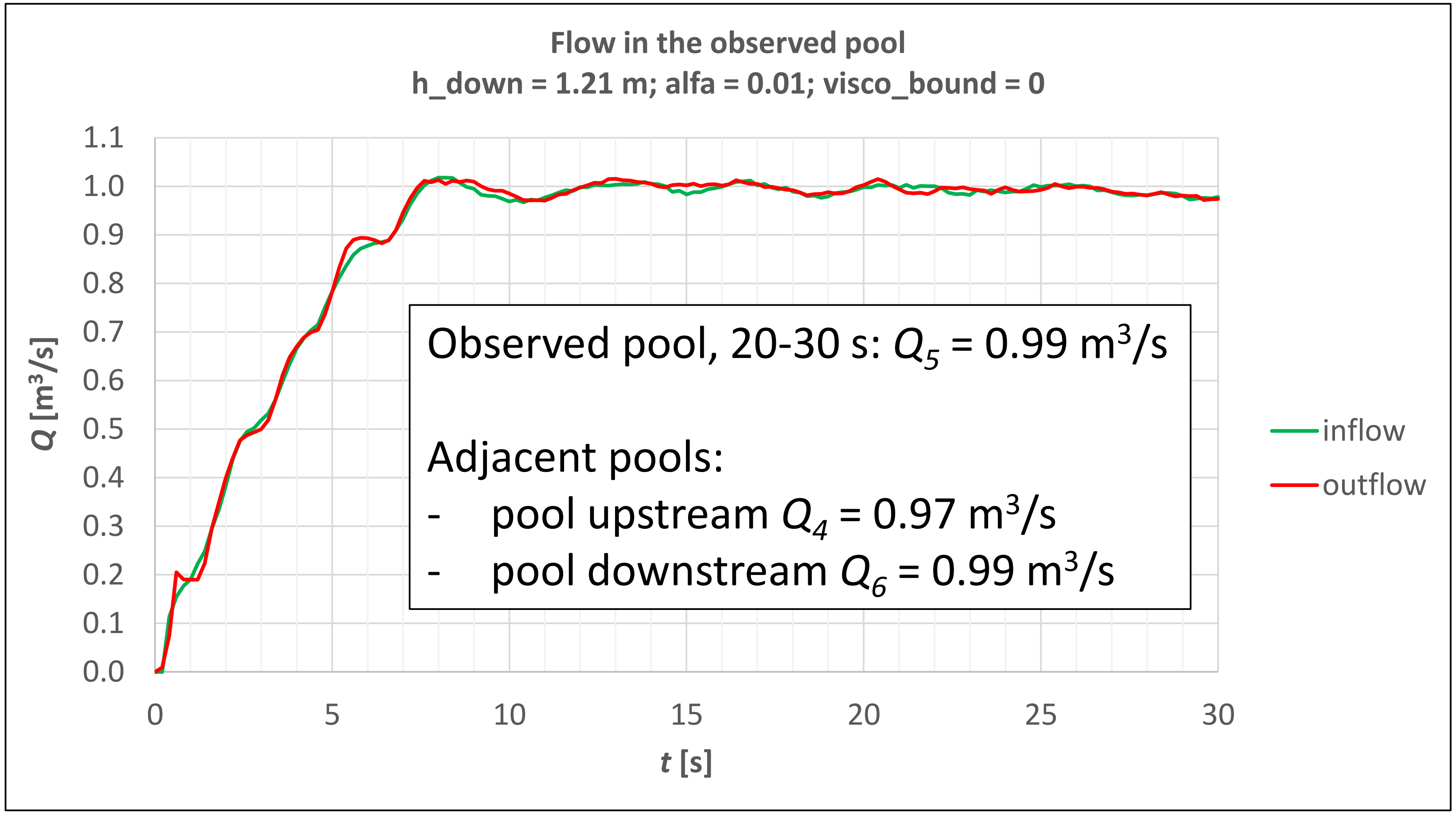
- PartVTK & IsoSurface Tool → export bound, fluid, iso → Para View



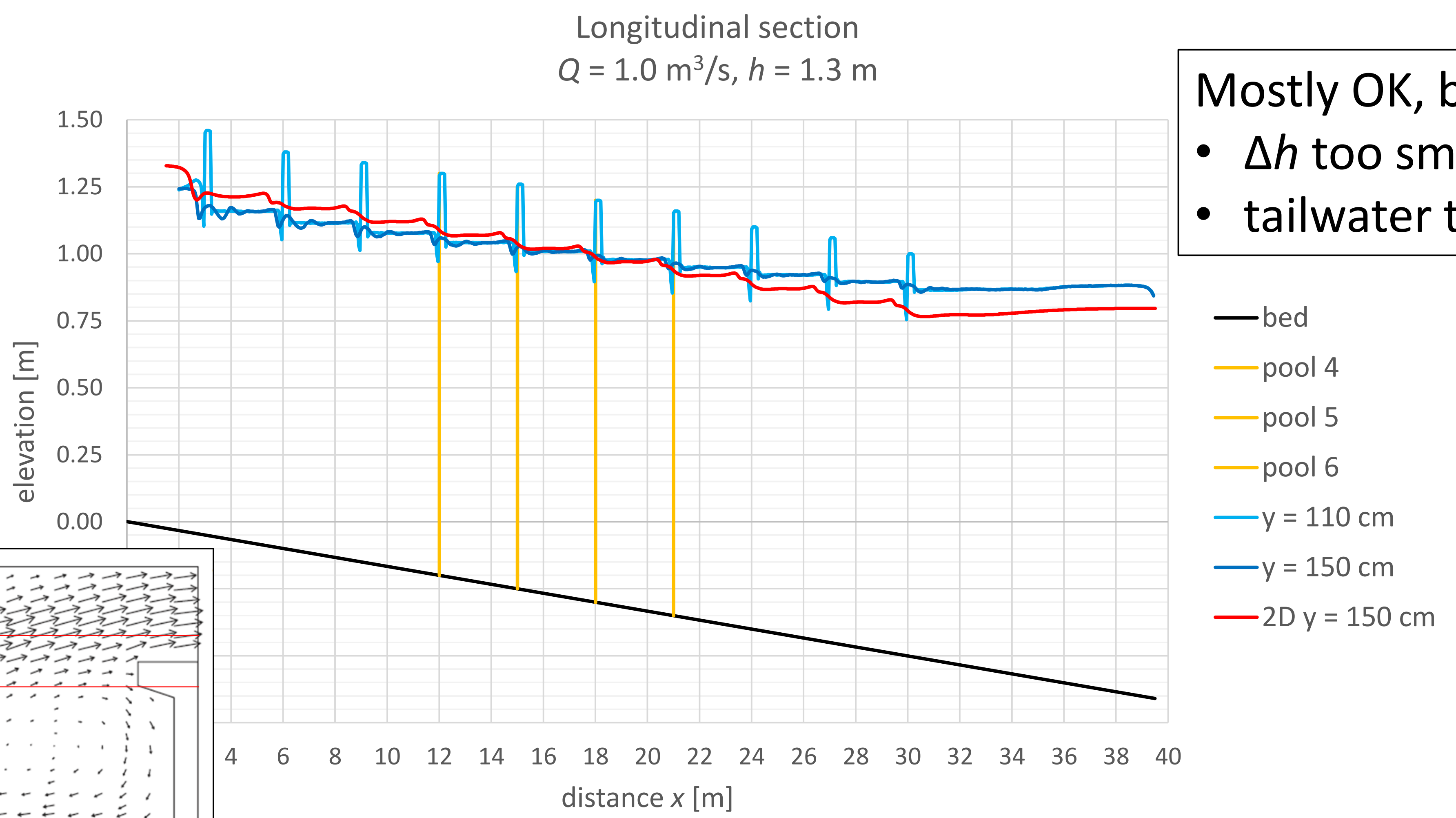
Flow Tool


FreeCAD
Box Name BOX
Using multiple boxes with the same name will produce only one volume to measure.
Use that to create prisms and complex forms. All points are specified in meters.
E
F
H
G
A
D
B
C
Z
Y
X
Point A (X, Y, Z) 16.0 2.2 -0.26
Point B (X, Y, Z) 16.0 0.0 -0.26
Point C (X, Y, Z) 17.0 0.0 -0.28
Point D (X, Y, Z) 17.0 2.2 -0.28
Point E (X, Y, Z) 16.0 2.2 1.5
Point F (X, Y, Z) 16.0 0.0 1.5
Point G (X, Y, Z) 17.0 0.0 1.48
Point H (X, Y, Z) 17.0 2.2 1.48
OK
Cancel


box

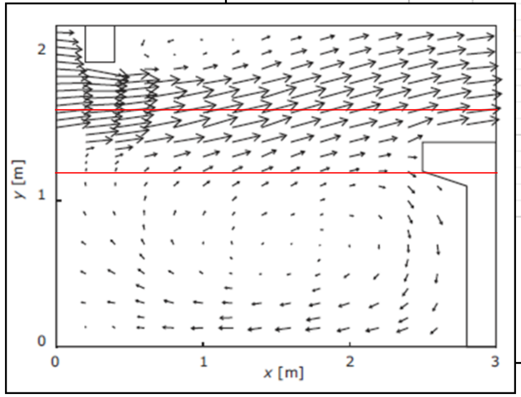

Flow in the observed pool
h_down = 1.21 m; alfa = 0.01; visco_bound = 0
Q [m³/s]
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
t [s]
Observed pool, 20-30 s: Q_5 = 0.99 m³/s
Adjacent pools:
- pool upstream Q_4 = 0.97 m³/s
- pool downstream Q_6 = 0.99 m³/s
inflow
outflow

Measure Tool – water surface elevation



Mostly OK, but:

- Δh too small (< 5 cm)!
- tailwater too high!



Measure Tool – velocity profiles

- Exported velocity components: *u*, *v*, *w*

MeasureTool Points

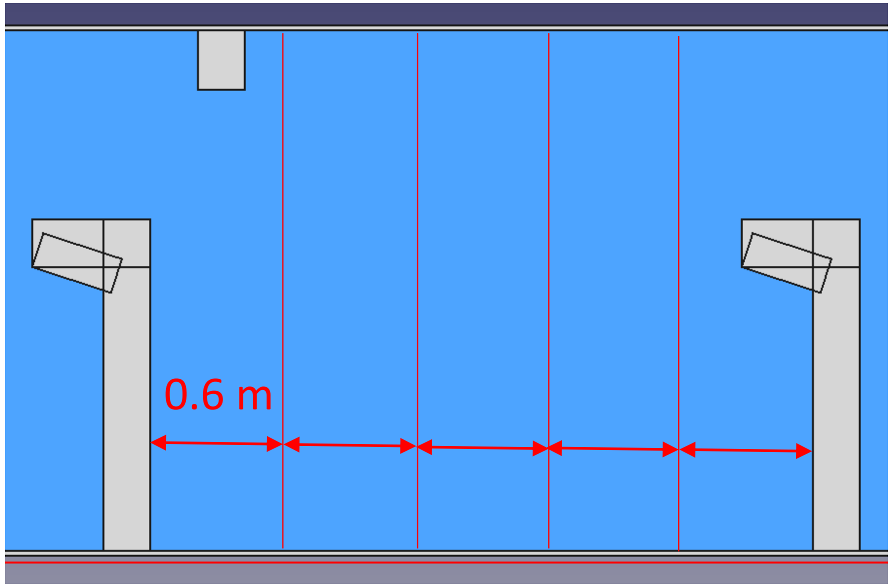
BeginX	BeginY	BeginZ	StepX	StepY	StepZ	CountX	CountY	CountZ
15.7	0.0	-0.21	0.0	0.02	0.0	1.0	111.0	1.0

- Focus on 4 profiles:

  $x = 60, 120, 180, 240$ cm

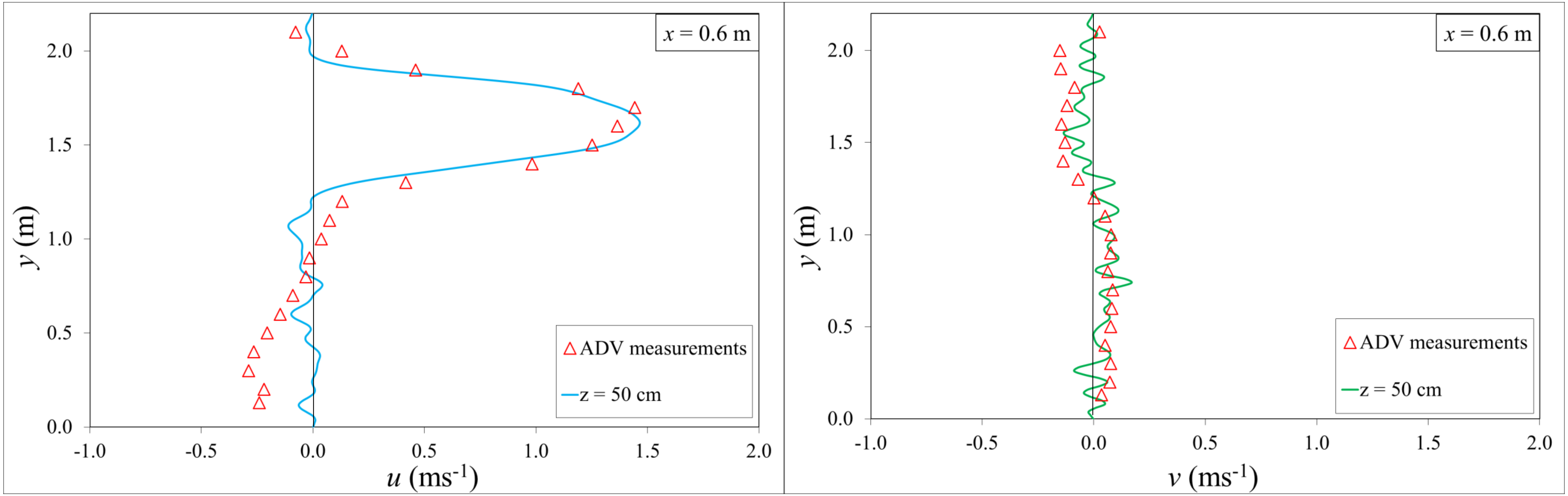
  $z = 5, 25, 50, 75, 100, 120$ cm

  step $y = 0, 2, 4, \ldots 220$ cm

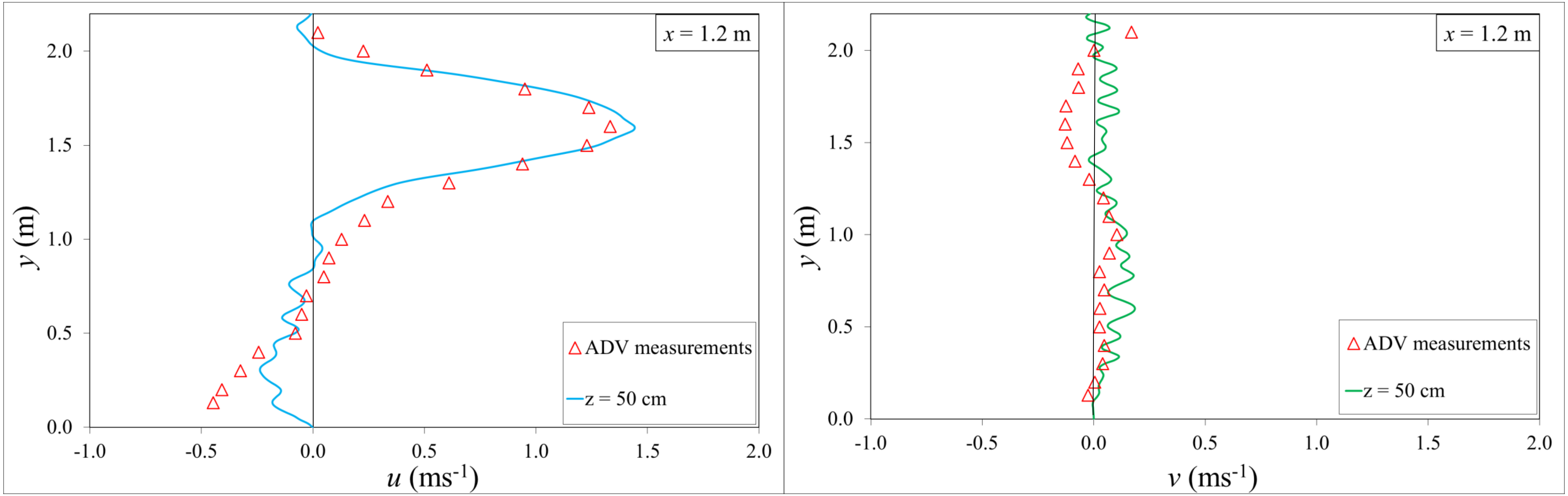


- Compared against ADV and 2D model

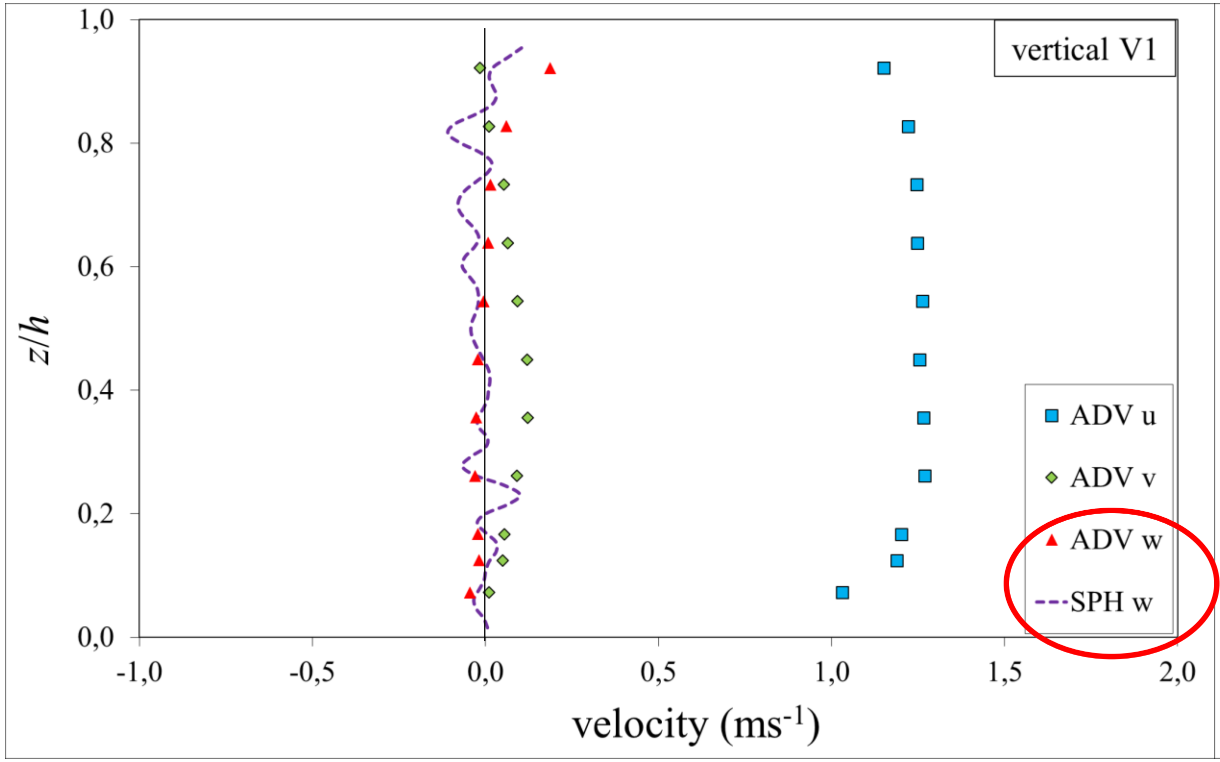
Dual SPHysics vs. ADV at z = 0.5 m, x = 0.6 m

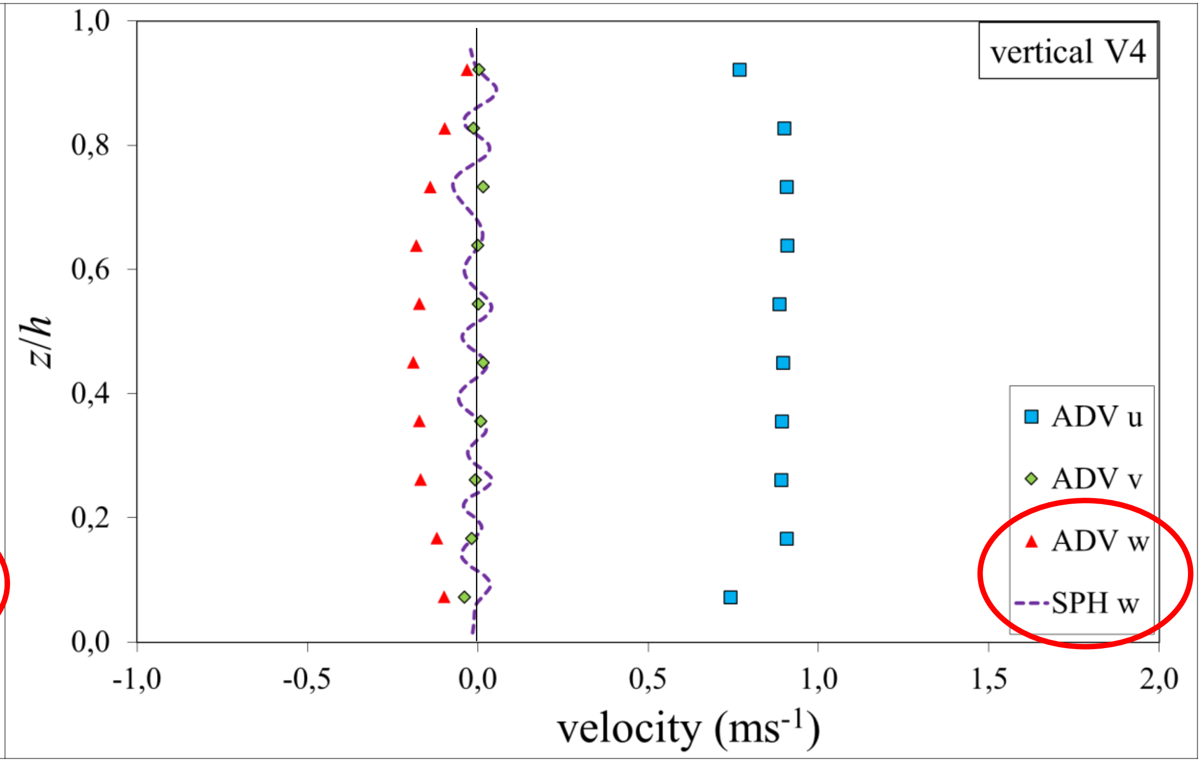


Dual SPHysics vs. ADV at z = 0.5 m, x = 1.2 m

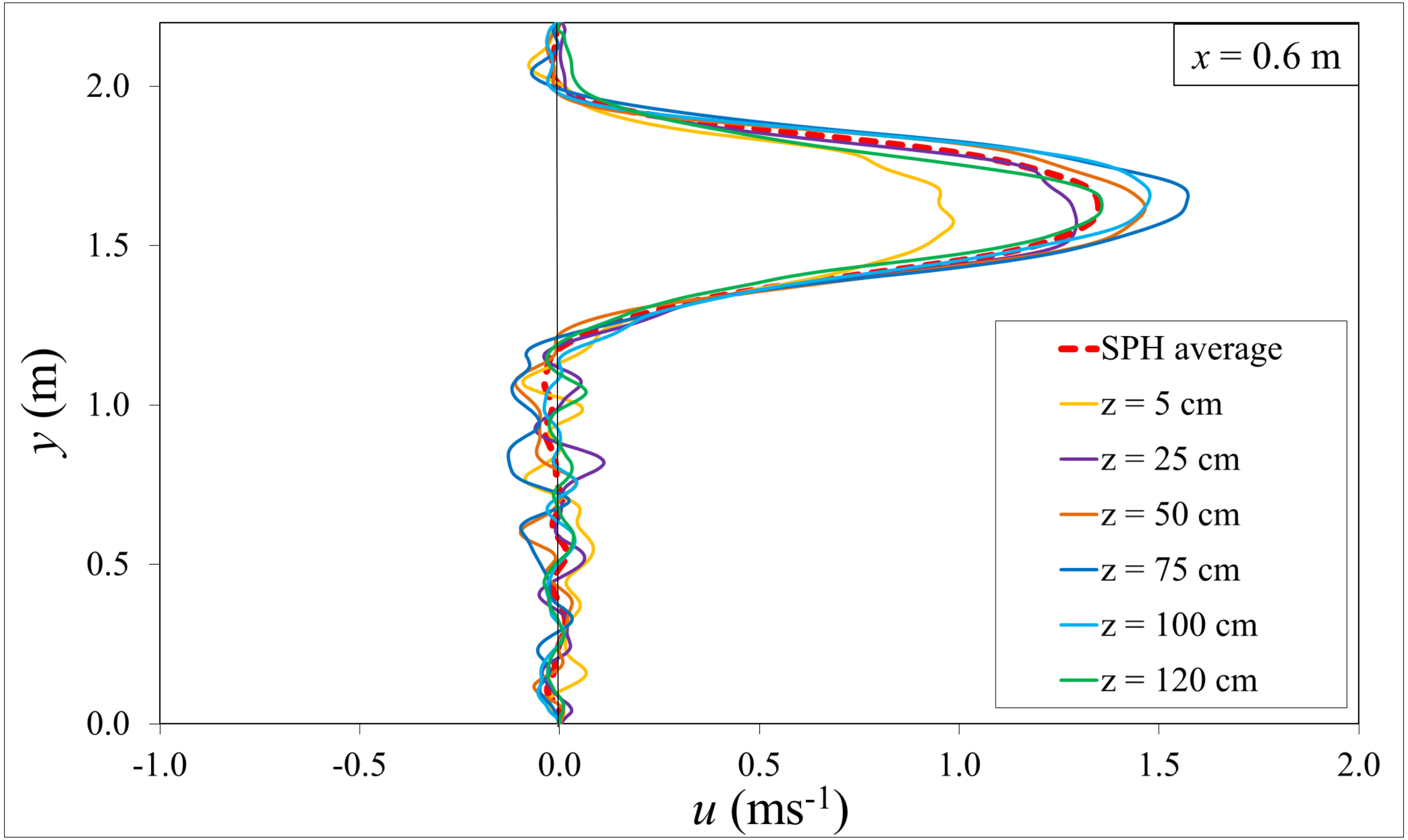


Dual SPHysics vs. ADV at verticals V1 and V4



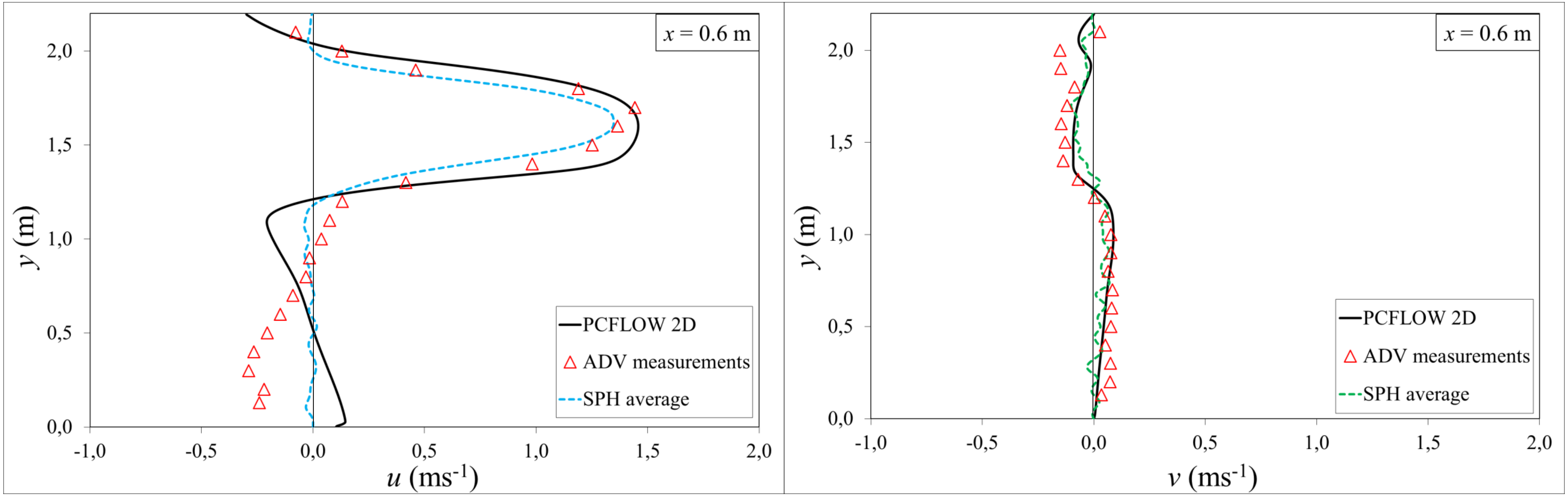


Average velocity profile

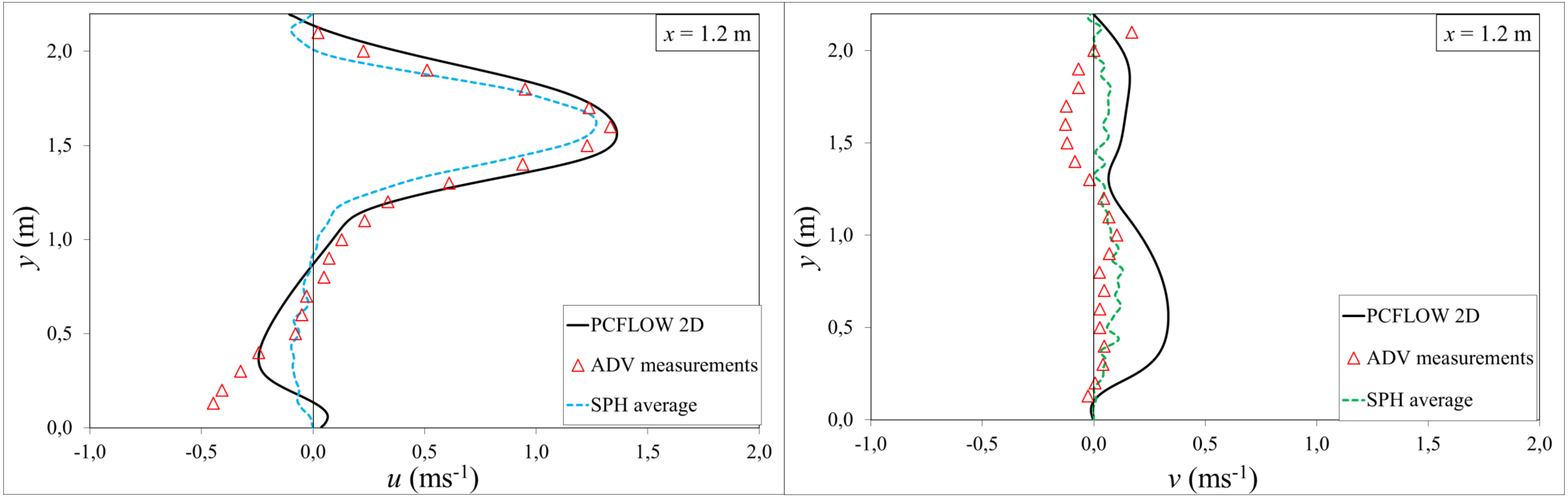


Average velocity profile (*u* or *v*) calculated from 6 profiles from *z* = 5 cm to *z* = 120 cm

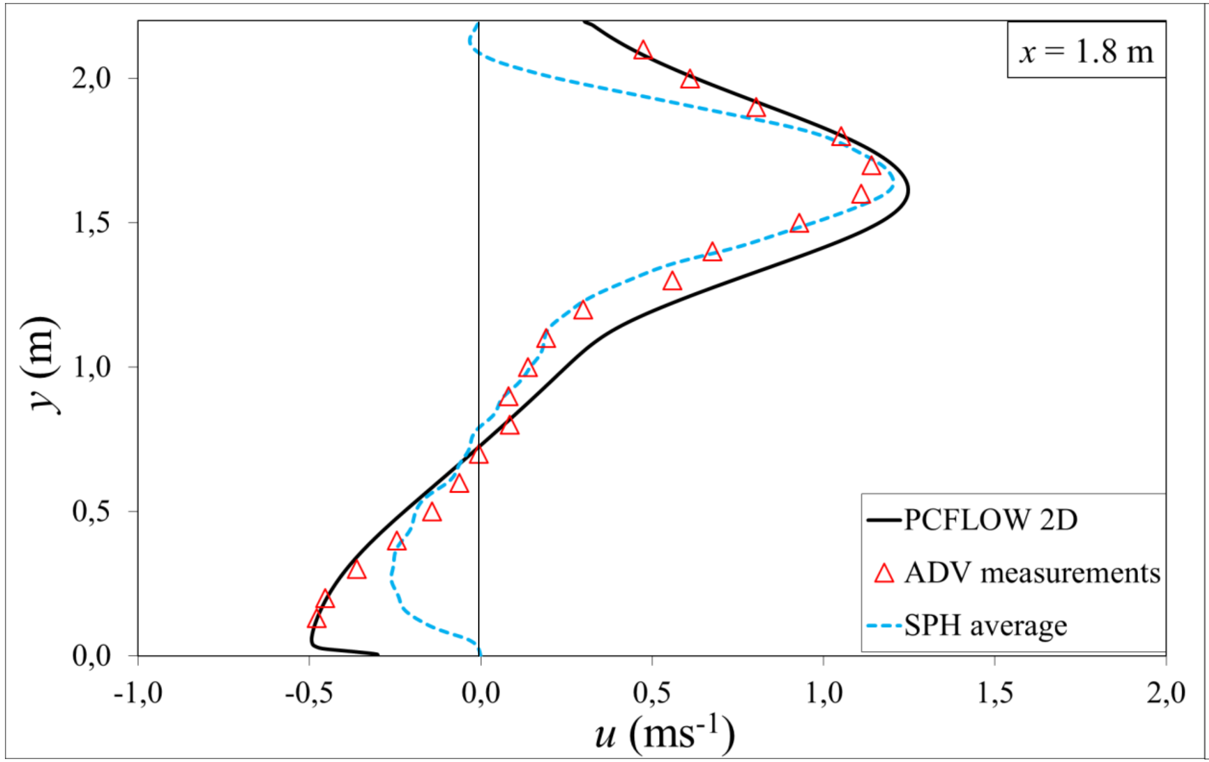
Average velocity profile at *x* = 60 cm

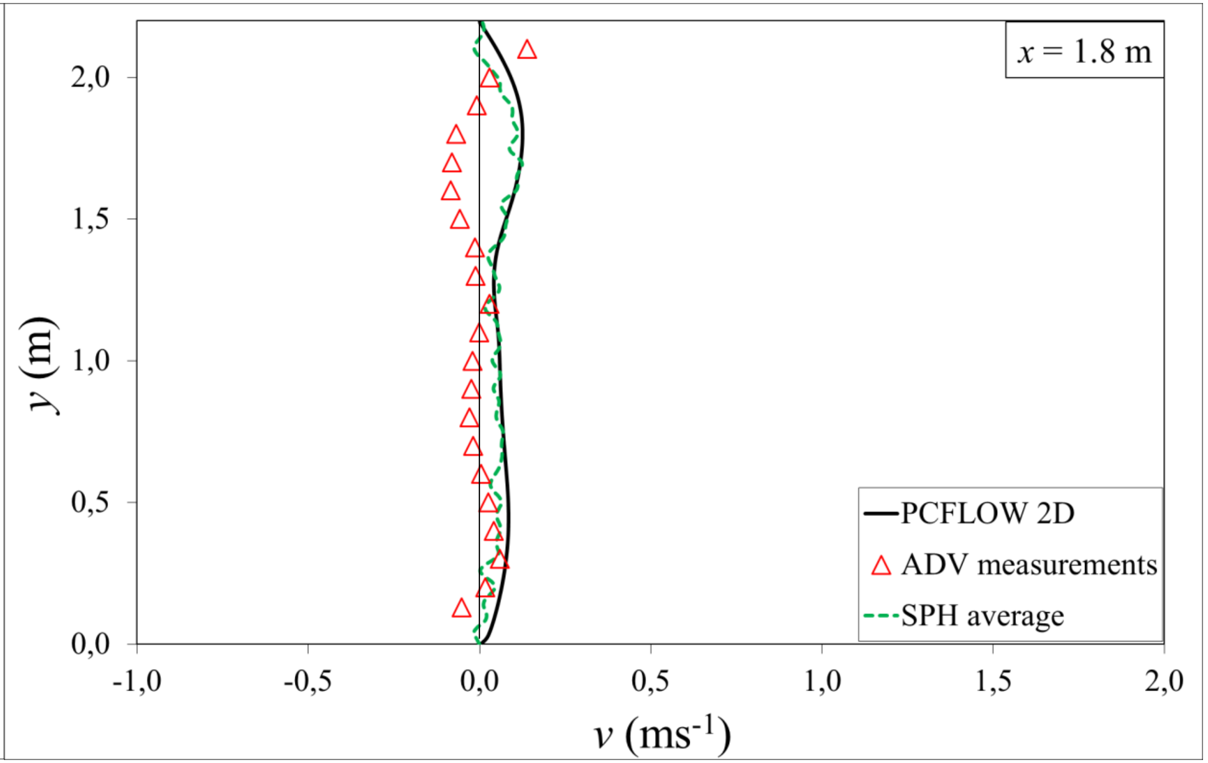


Average velocity profile at x = 120 cm

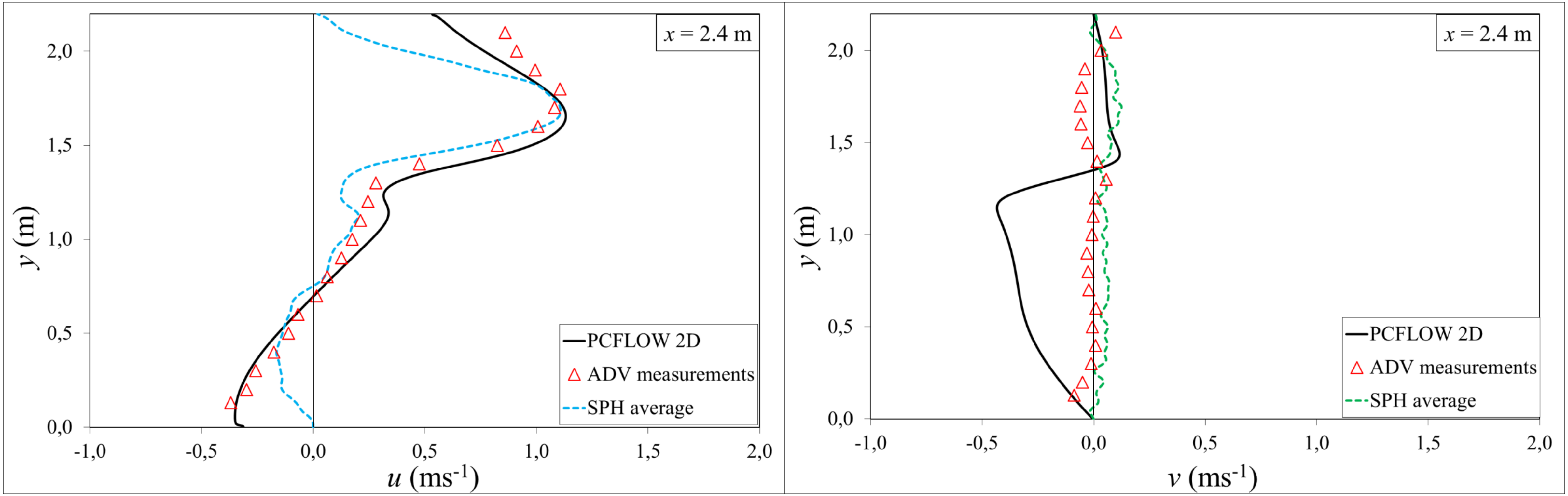


Average velocity profile at x = 180 cm





Average velocity profile at *x* = 240 cm



Conclusion

- Initial fluid object + periodic boundary condition: OK (*Q* & *h* pool)
- Water surface elevation: Δ*h* too small, tailwater level too high
- Velocity field: mostly OK, with some discrepancies
- Possible issues: vortices near the slot, flow over the sharp edge of the downstream wall

- Further work: determine the effect of various execution parameters (*dp*, *α*, visco_bound, laminar + SPS viscosity …)

Looking forward to test the inlet/outlet boundary condition

References

- Bombač, M. et al., 2017. Study on flow characteristics in vertical slot fishways regarding slot layout optimization. *Ecological Engineering* 107, 126-136.

- Bombač, M. et al., 2015. Extensive field measurements of flow in vertical slot fishway as data for validation of numerical simulations. *Ecological Engineering* 84, 476-484.

- Bombač, M. et al., 2014. Numerical and physical model study of a vertical slot fishway. *Journal of Hydrology and Hydromechanics* 62 (2), 1-10.