River Flow 2014
International Conference on Fluvial Hydraulics
September 3-5 | Lausanne | Switzerland

Image-based velocity and discharge measurements in field and laboratory river engineering studies using the free FUDAA-LSPIV software

Jérôme LE COZ[1], Magali JODEAU[2], Alexandre HAUET[3], Bertrand MARCHAND[4], Raphaël LE BOURSICAUD[1]

[1] ***Irstea**, Hydrology-Hydraulics, Lyon, France*
[2] ***EDF R&D**, LNHE, Chatou France*
[3] ***EDF DTG**, Grenoble, France*
[4] ***DeltaCAD**, Lacroix Saint-Ouen, France*

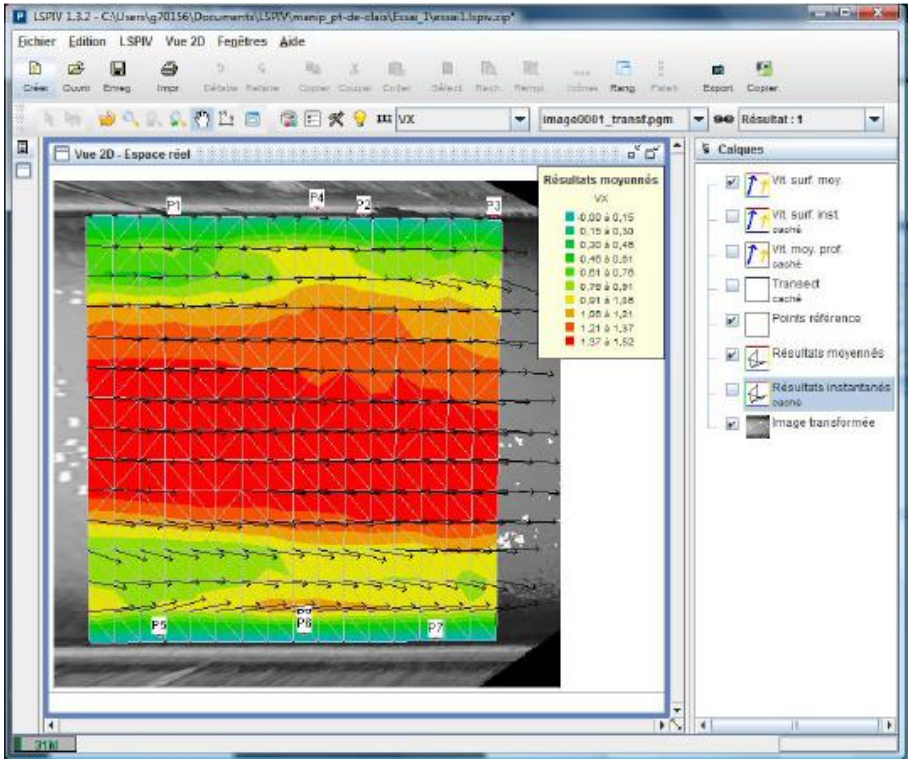


Image-based velocity and discharge measurements using the free FUDAA-LSPIV software

Purposes and principles of the LSPIV technique

→ *Advantages of image-based non intrusive velocimetry*

→ *Principles of LSPIV*

Implementation in the Fudaa-LSPIV software

→ *The development project*

→ *Structure and functions*

Example of applications

→ *Laboratory: recirculation flow in a meander outlet*

→ *Field: flood streamgauging from YouTube home movies*

Advantages of image-based non intrusive velocimetry

- 2-D instantaneous velocity field at the free-surface
- Non contact measurements (safe, convenient)
- Development of digital imagery and increasing amount of flood movies

Groyne experiments (IIHR, University of Iowa)

Flash-flood of the Ouvèze river (1992), France

Principles of the LSPIV technique

Step 1. Record image sequences with accurate time intervals

- Flow tracers should be visible, dense and representative
- Lighting: avoid reflections, shadows, glittering, etc.

Principles of the LSPIV technique

Step 2. Implicit camera calibration using fixed ground reference points (GRPs)

→ at least 6, well distributed throughout the area of interest

→ either 2D (same Z) or 3D (GRPs with different elevations)

$$i = \frac{a_1 X + a_2 Y + a_3 Z + a_4}{a_9 X + a_{10} Y + a_{11} Z + 1}$$

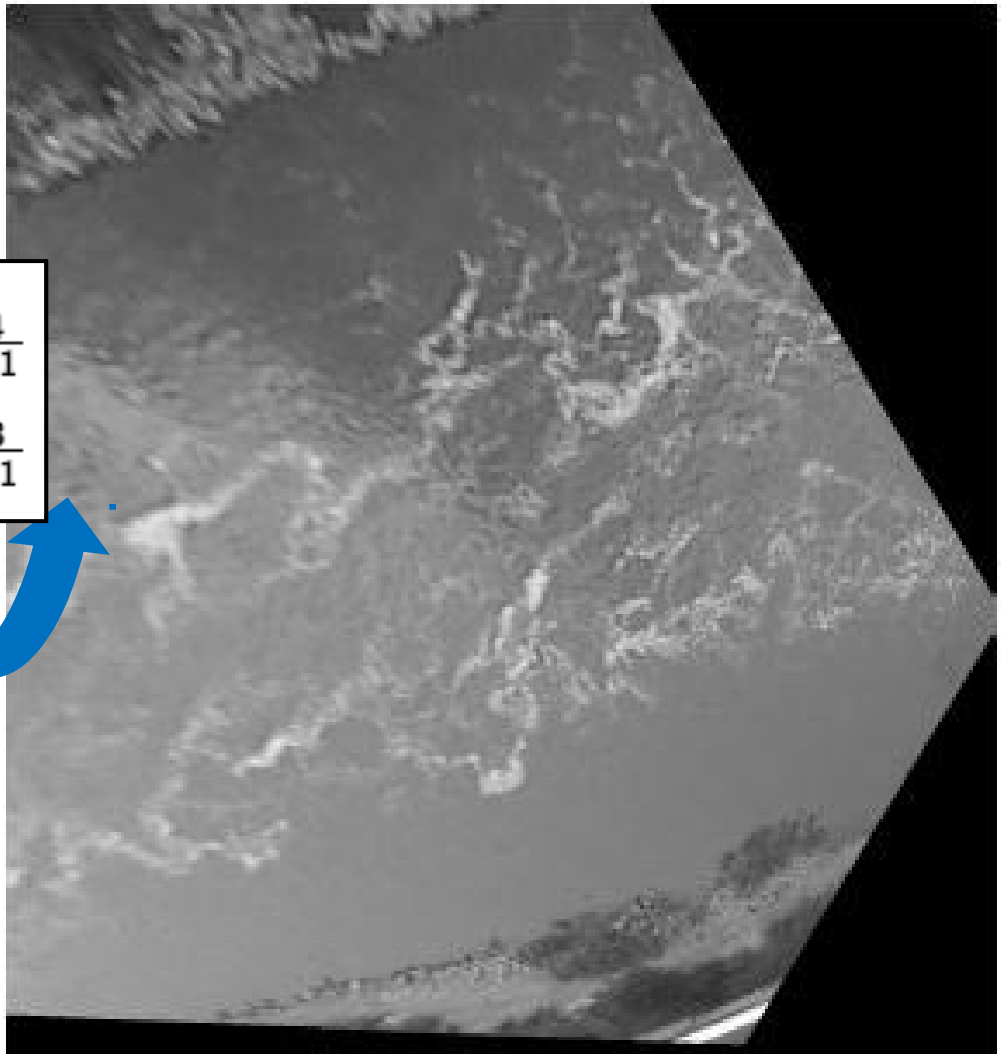
$$j = \frac{a_5 X + a_6 Y + a_7 Z + a_8}{a_9 X + a_{10} Y + a_{11} Z + 1}$$

Principles of the LSPIV technique

Step 3. Orthorectification of gray-scale images

$$i = \frac{a_1 X + a_2 Y + a_3 Z + a_4}{a_9 X + a_{10} Y + a_{11} Z + 1}$$

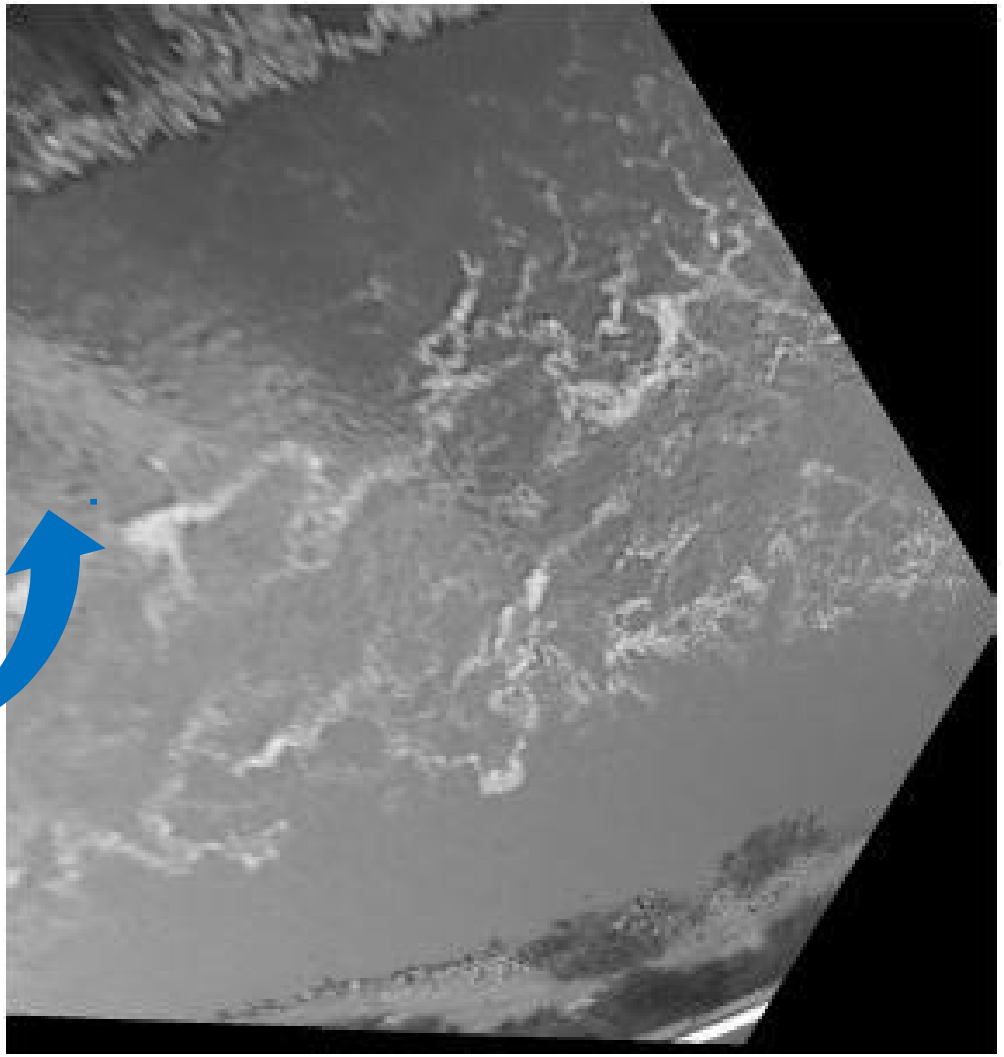
$$j = \frac{a_5 X + a_6 Y + a_7 Z + a_8}{a_9 X + a_{10} Y + a_{11} Z + 1}$$



Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

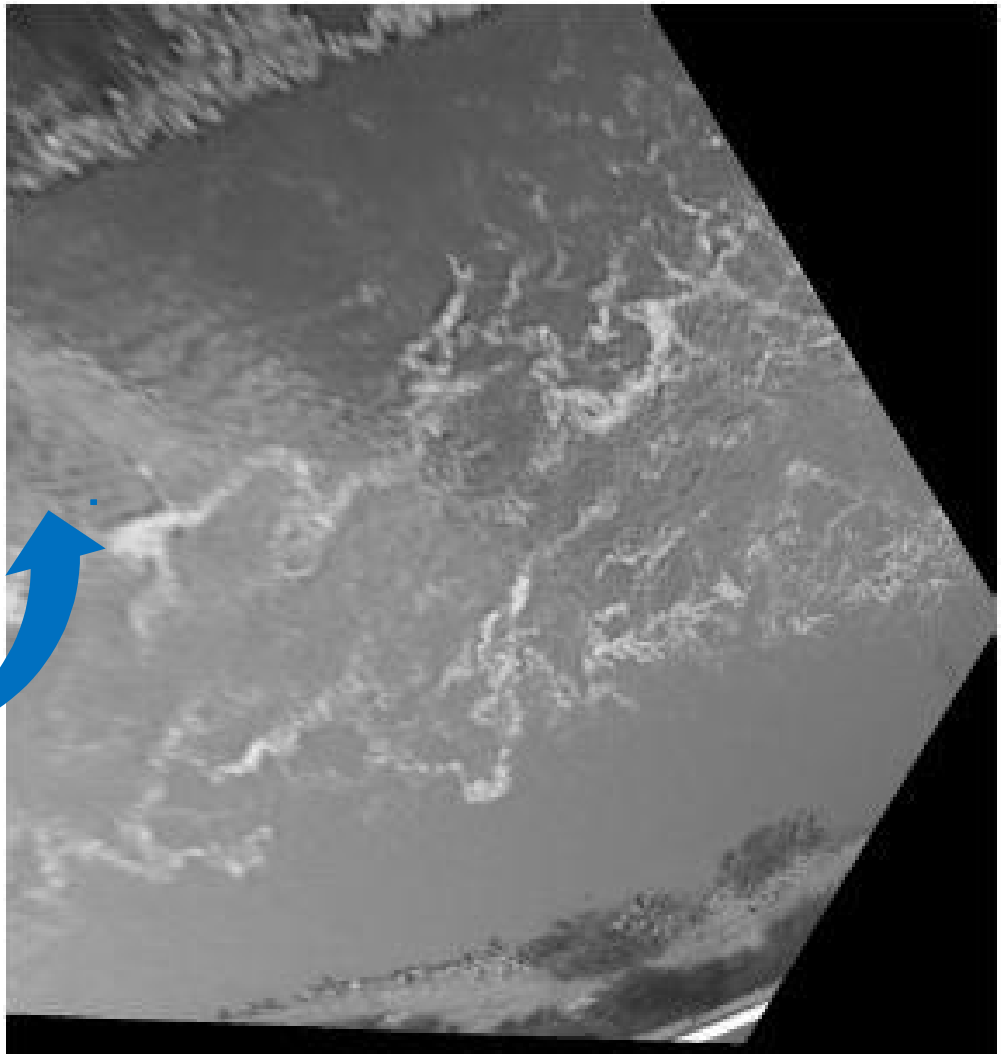
→ artificial seeding or natural tracers (floating objects, turbulence patterns, etc.)



Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

→ artificial seeding or natural tracers (floating objects, turbulence patterns, etc.)

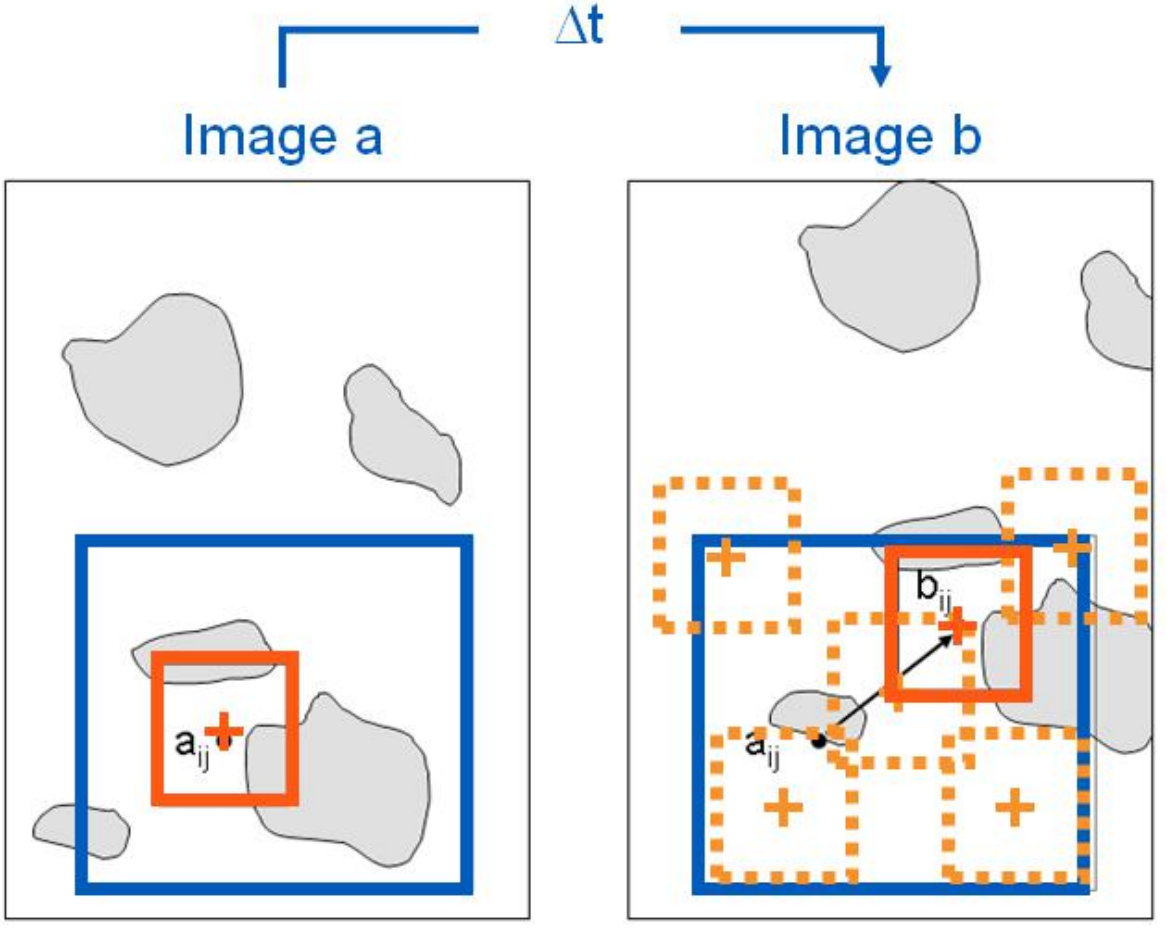


Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

→ based on cross-correlation analysis

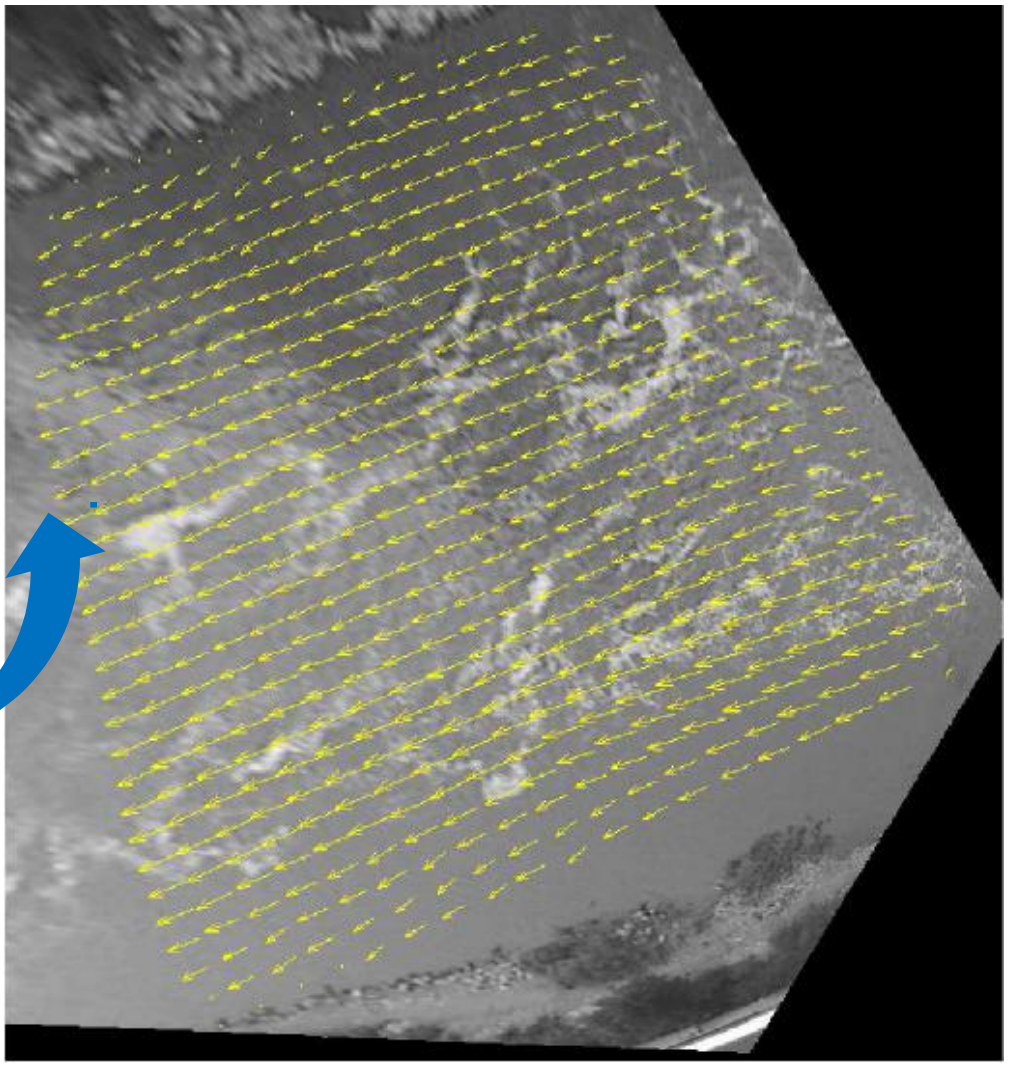
→ the centre of the Interrogation Area travels within a Search Area



Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

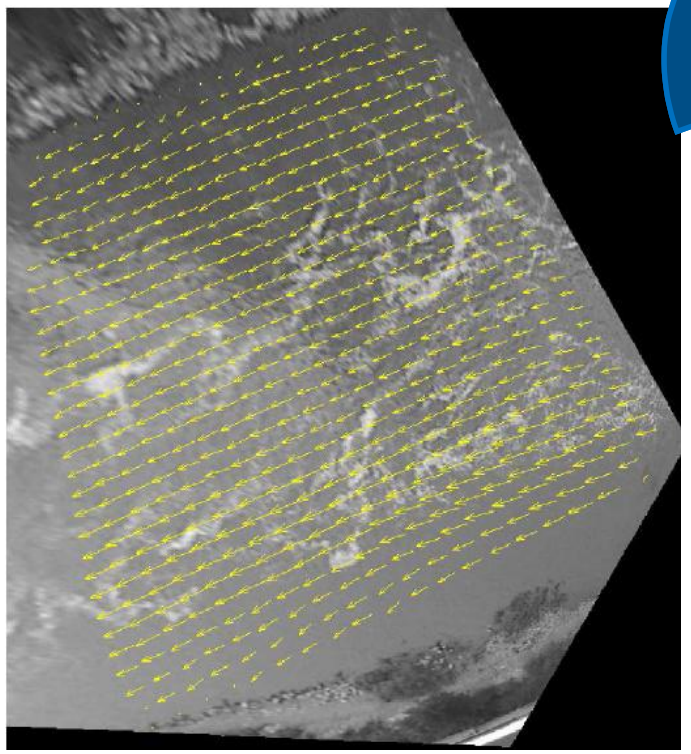
→ **computation of surface velocity vectors**



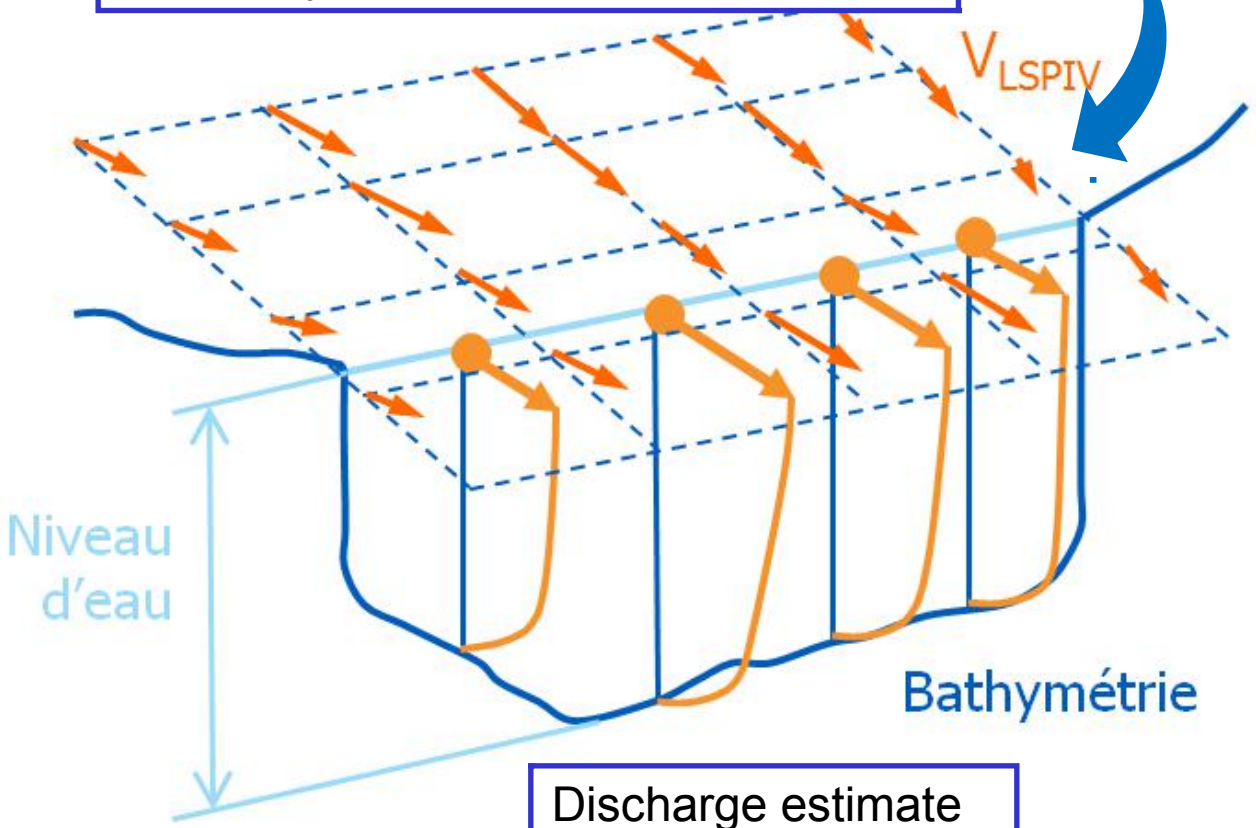
Principles of the LSPIV technique

Step 5. Estimation of discharge through a known cross-section

→ velocity-area method based on a constant depth-acerage to surface velocity ratio



+ Bathymetry profile
+ Velocity distribution model



Discharge estimate

Fudaa-LSPIV software: The development project

Co-development EDF, Irstea and implementation by DeltaCAD

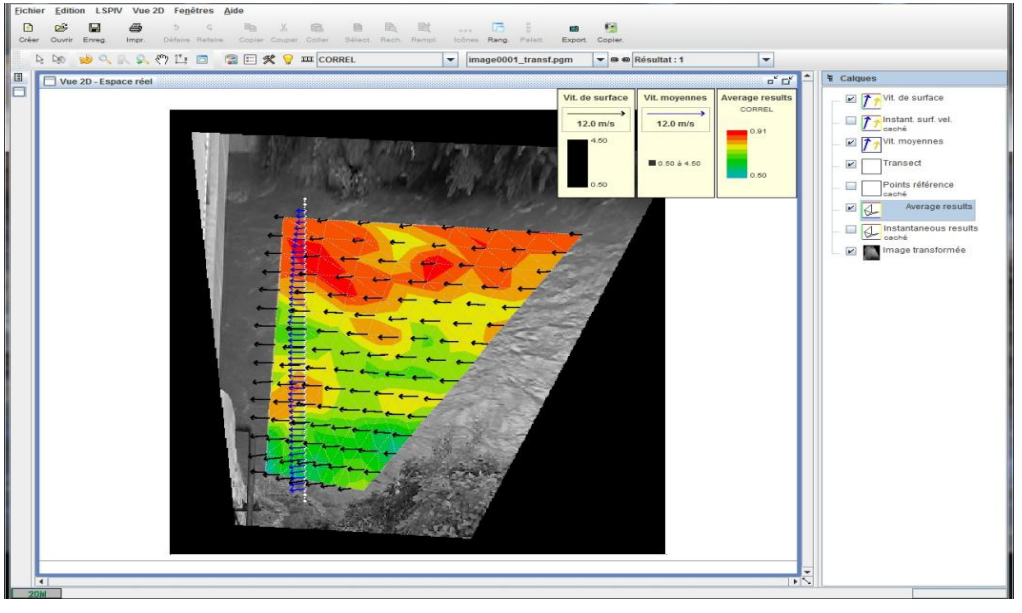
- Fortran solvers (parallelised) developed by EDF and Irstea scientists
- Java graphical environment developed by DeltaCAD (since 2009)

Sharing the method and software

- Free release under GPL license (open-source)
- Windows / Linux binaries on public forge
- User manual in French and in English
- Interface languages: French, English
- Forge: https://forge.irstea.fr/projects/fudaa-lspiv

Further developments

- Corrective maintenance
- Additional scalars and outputs
- Streamlines
- Discharge computation options
- Other velocimetry techniques (STIV, optical flow)



Fudaa-LSPIV software: Structure and functions

Pre-processing of images:

→ sample image sequence from movies (e.g. using VirtualDUB)

→ convert images to PGM ASCII format (e.g. using XnView)

Processing data step by step:

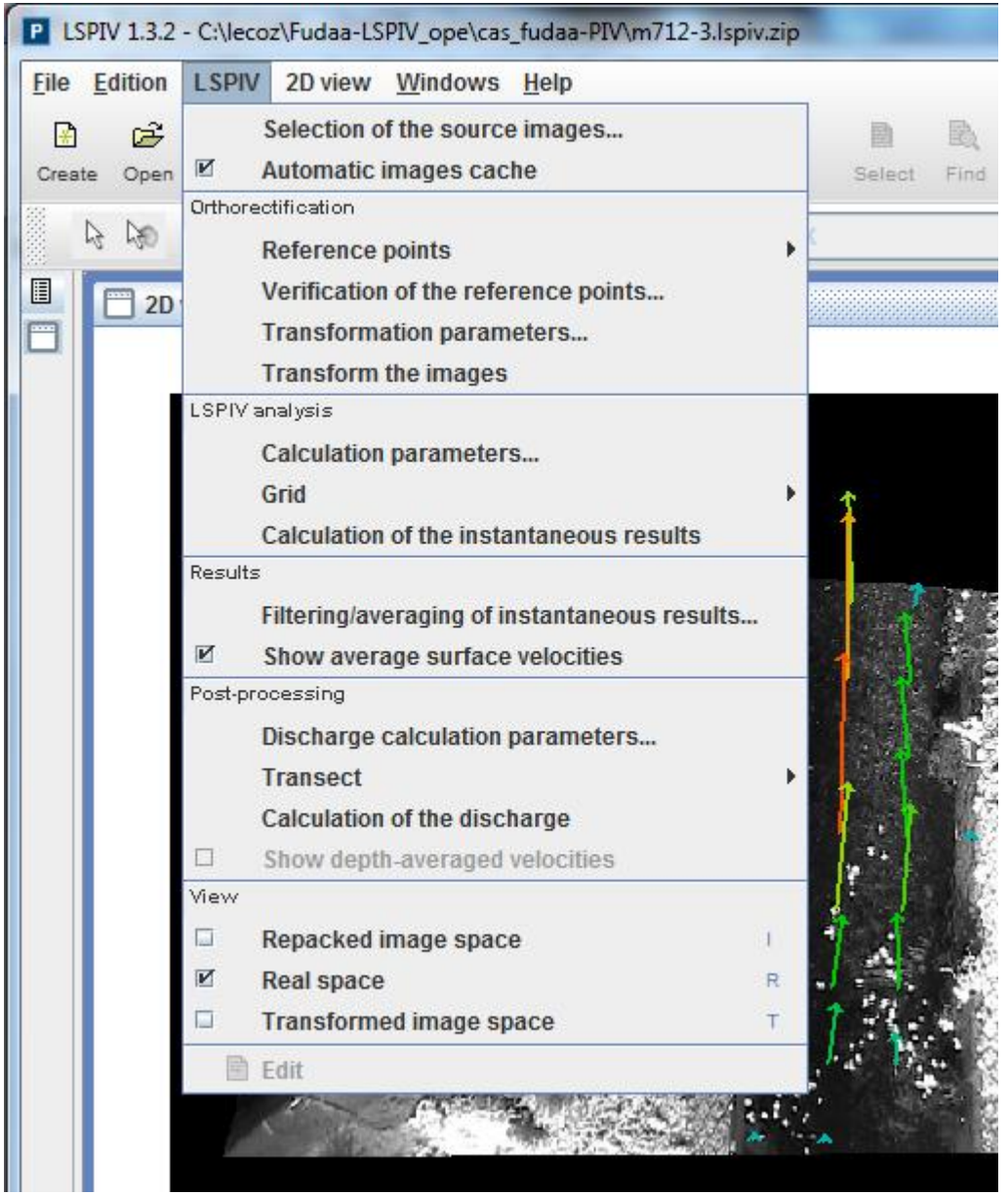
→ Source images

→ Orthorectification

→ PIV analysis

→ Results processing

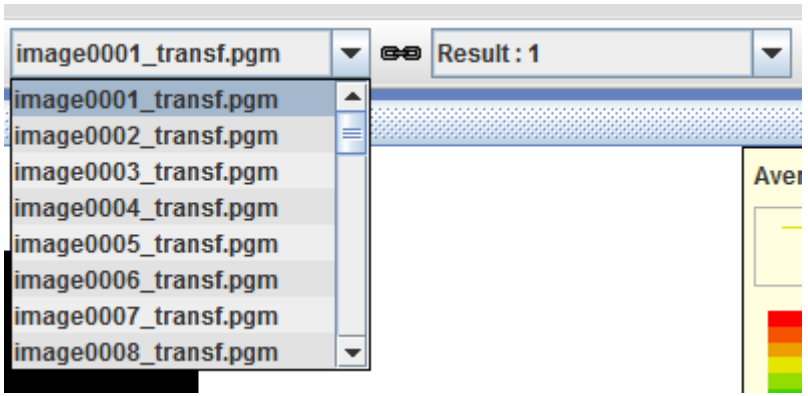
→ Discharge computation

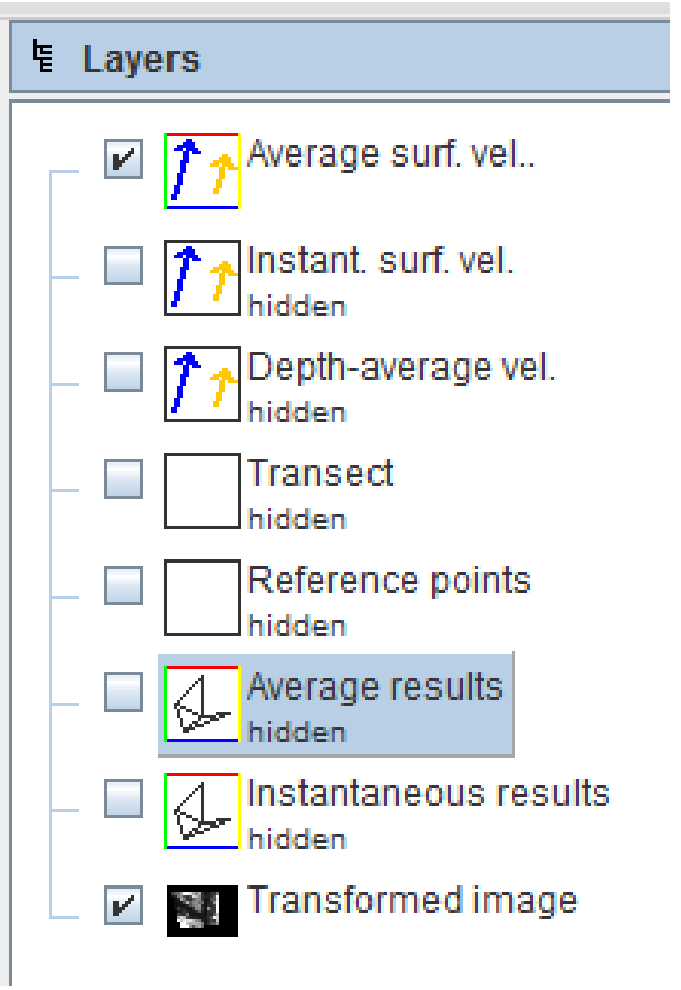


Fudaa-LSPIV software: Structure and functions

Visualization and exportations:

- layers, variables
- editable captions
- animation, data and picture outputs

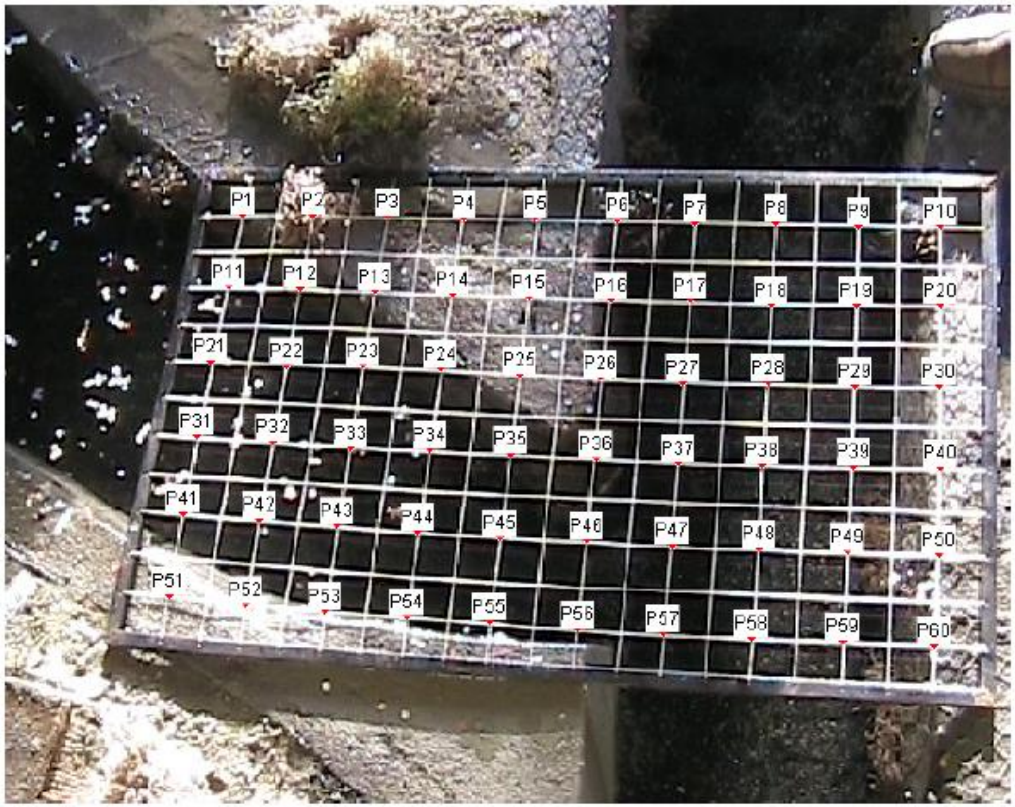


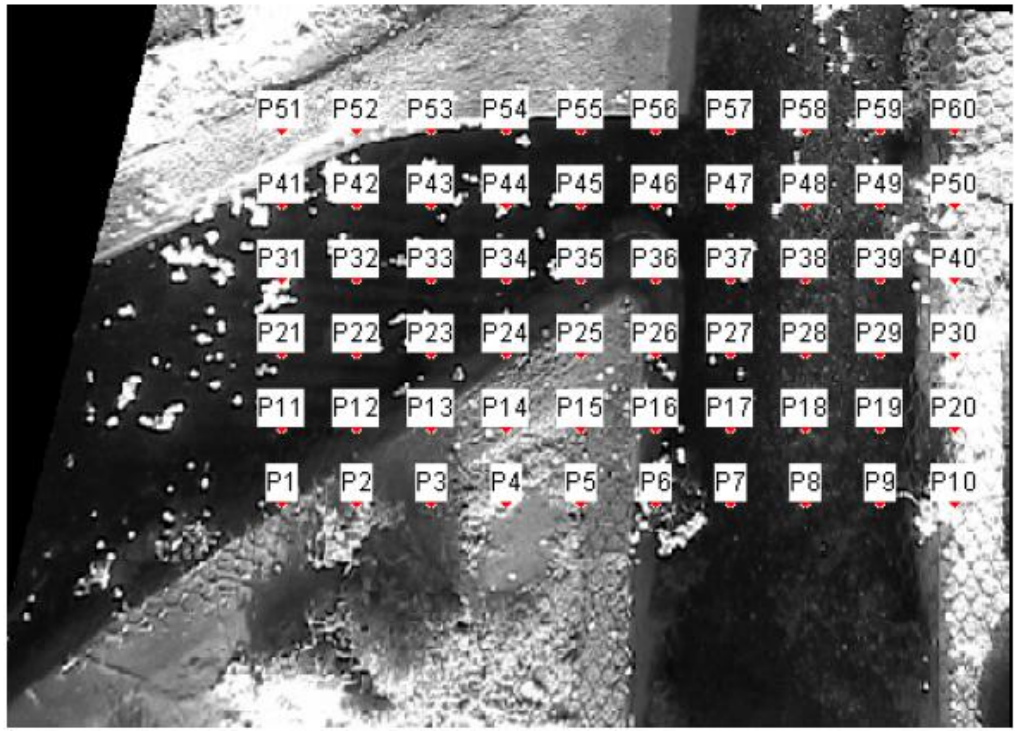


Laboratory: recirculation flow in a meander outlet

Physical model of the Morava River to design the reconnection of cut-off meanders (VUVH, Bratislava, Slovakia, cf. *Le Coz et al., ESPL, 2010*)

Defining GRPs...

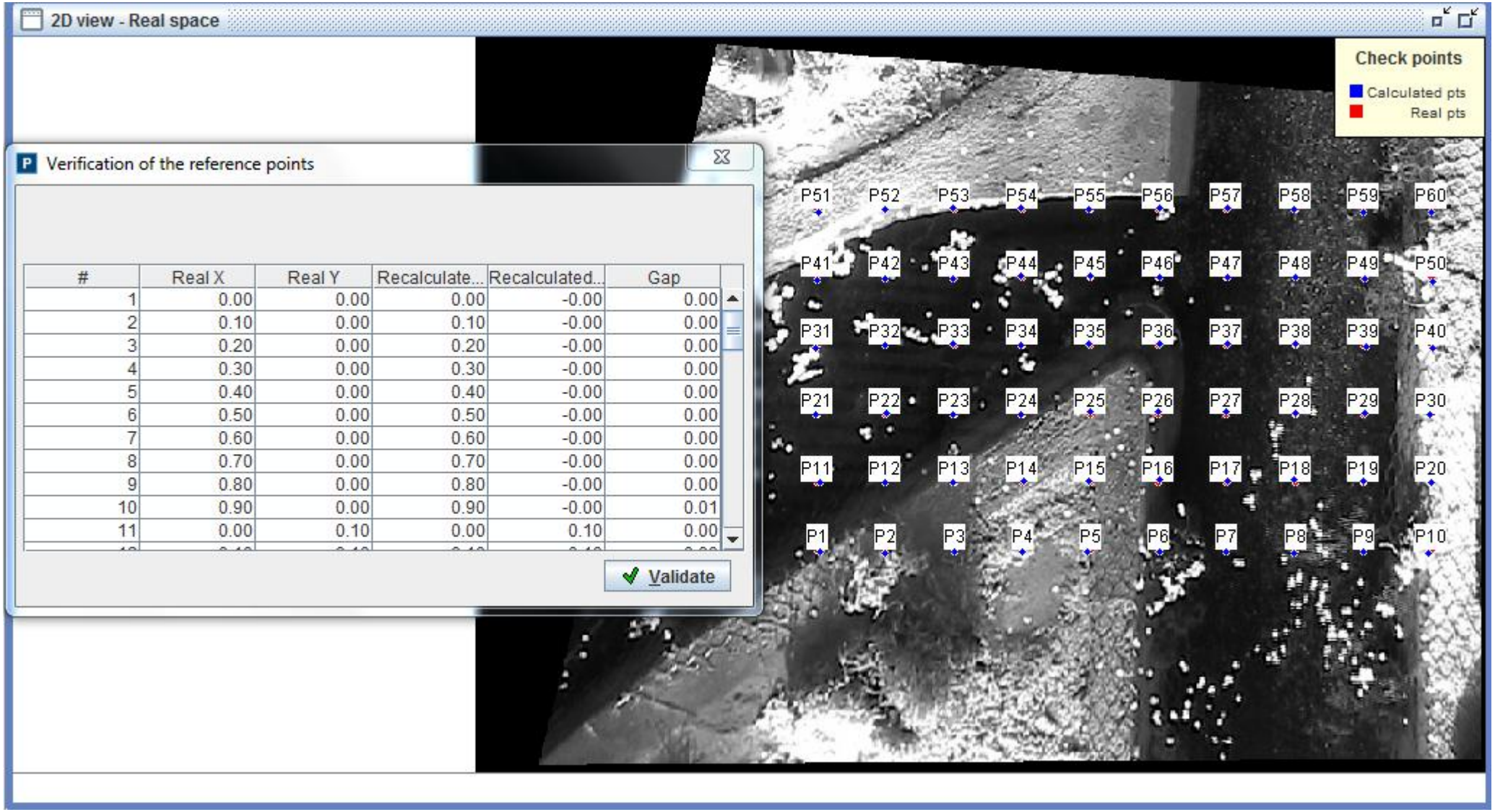




Laboratory: recirculation flow in a meander outlet

Verification of the accuracy of the orthorectification matrix:

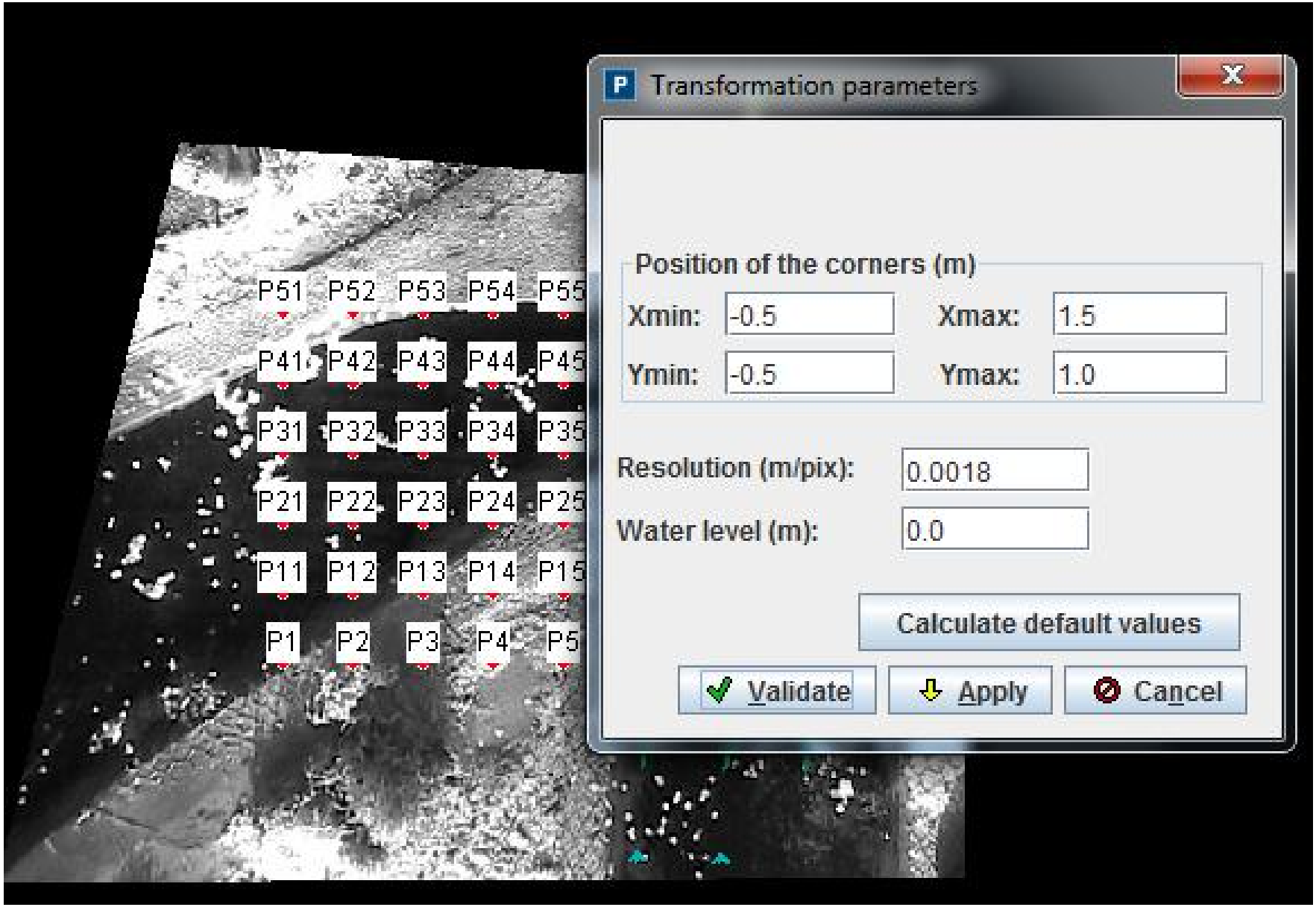
Comparison of the real and computed positions of GRPs



#	Real X	Real Y	Recalculate...	Recalculated...	Gap
1	0.00	0.00	0.00	-0.00	0.00
2	0.10	0.00	0.10	-0.00	0.00
3	0.20	0.00	0.20	-0.00	0.00
4	0.30	0.00	0.30	-0.00	0.00
5	0.40	0.00	0.40	-0.00	0.00
6	0.50	0.00	0.50	-0.00	0.00
7	0.60	0.00	0.60	-0.00	0.00
8	0.70	0.00	0.70	-0.00	0.00
9	0.80	0.00	0.80	-0.00	0.00
10	0.90	0.00	0.90	-0.00	0.01
11	0.00	0.10	0.00	0.10	0.00

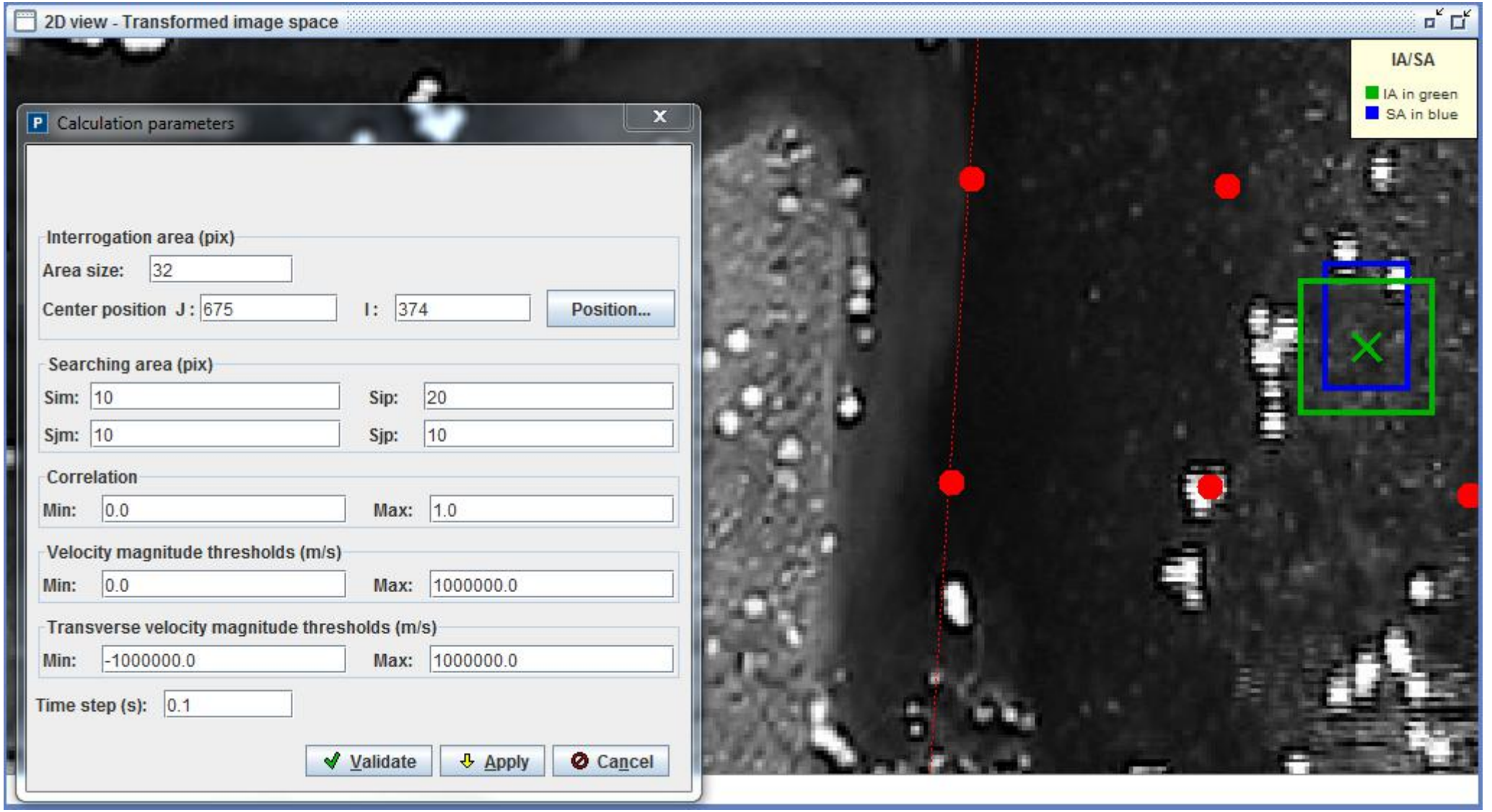
Laboratory: recirculation flow in a meander outlet

Definition of image transformation parameters



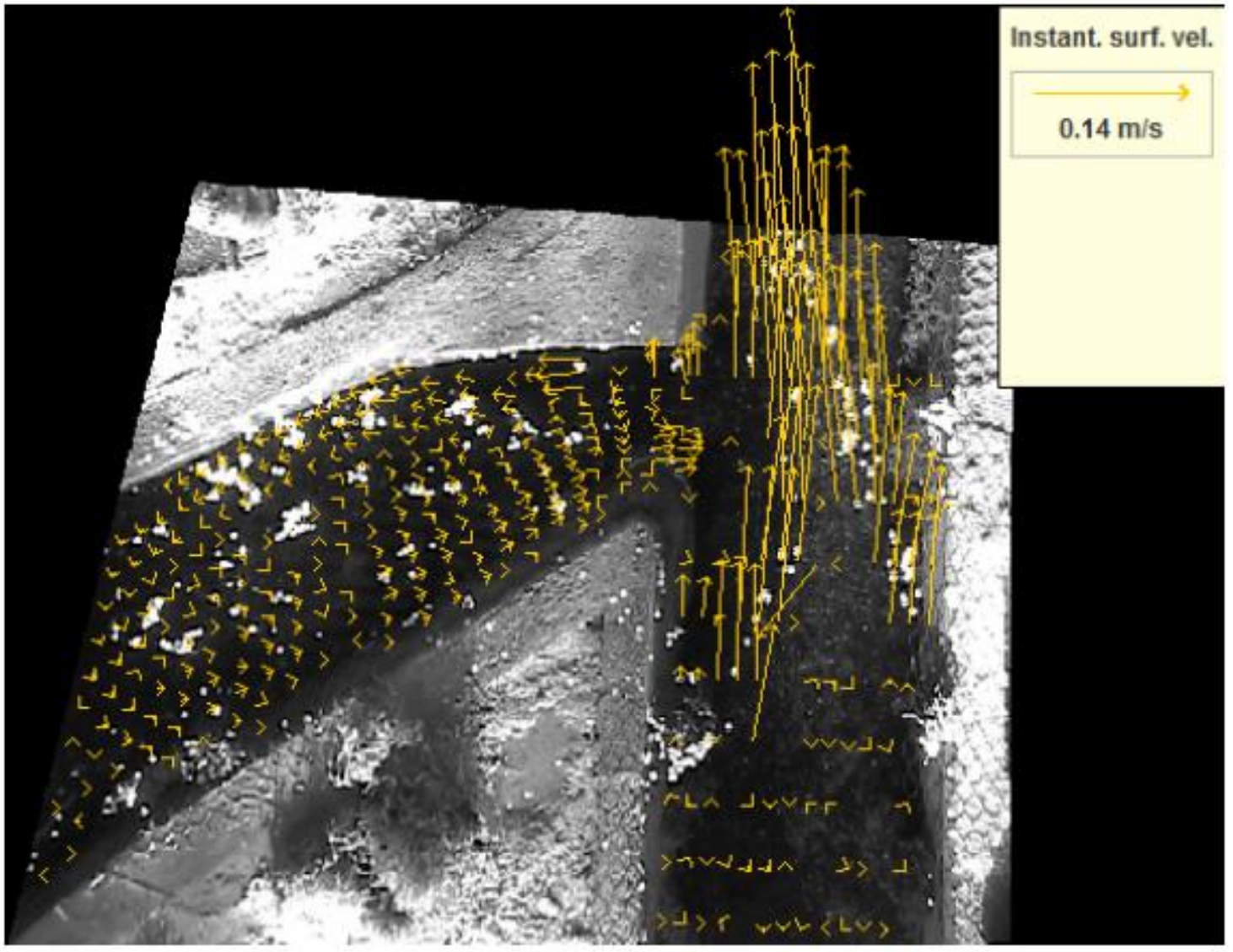
Laboratory: recirculation flow in a meander outlet

Definition of PIV computation parameters : grid nodes, interrogation area, search area, time interval, data screening thresholds



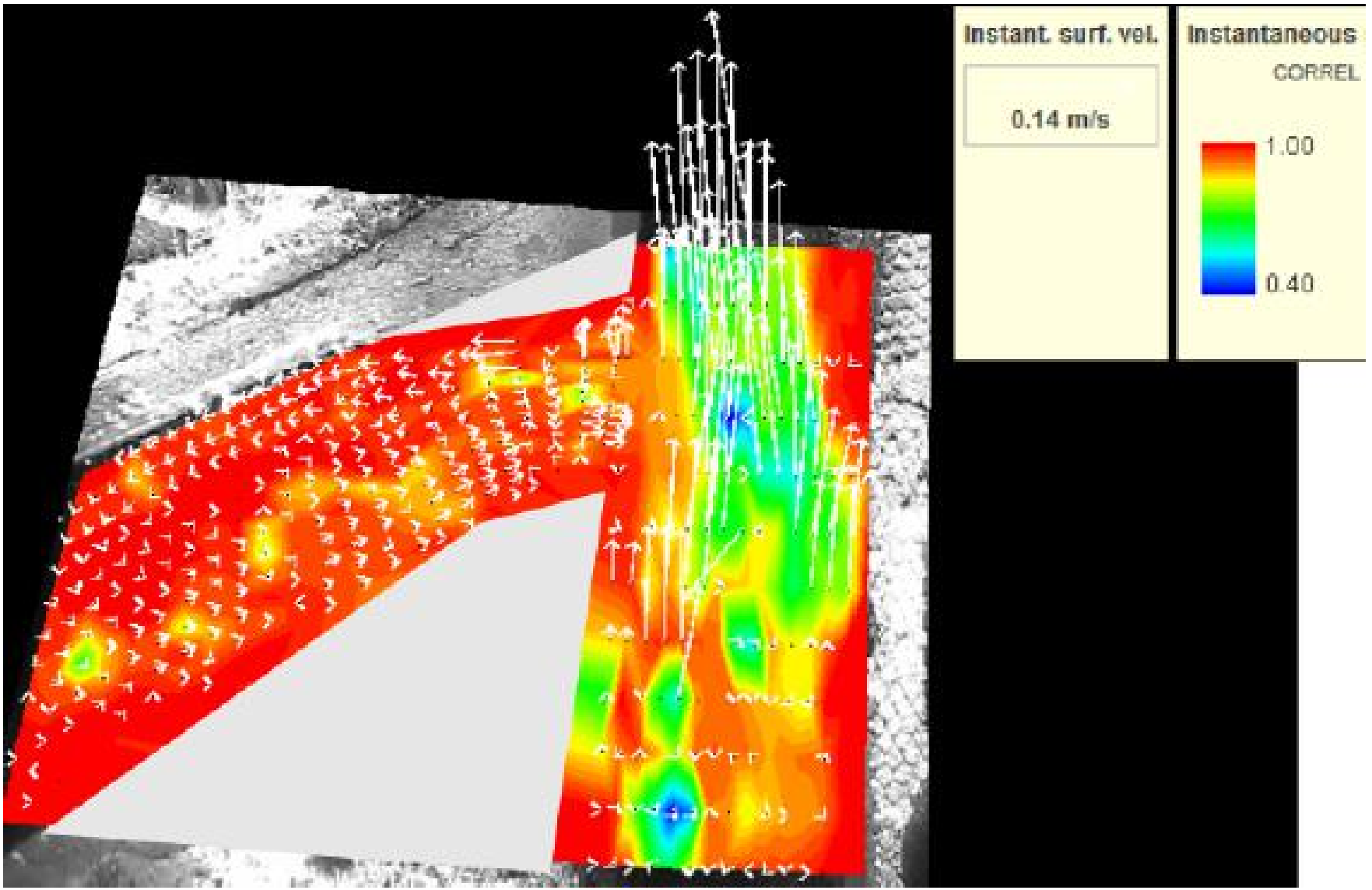
Laboratory: recirculation flow in a meander outlet

Instantaneous velocity field (1 image pair)



Laboratory: recirculation flow in a meander outlet

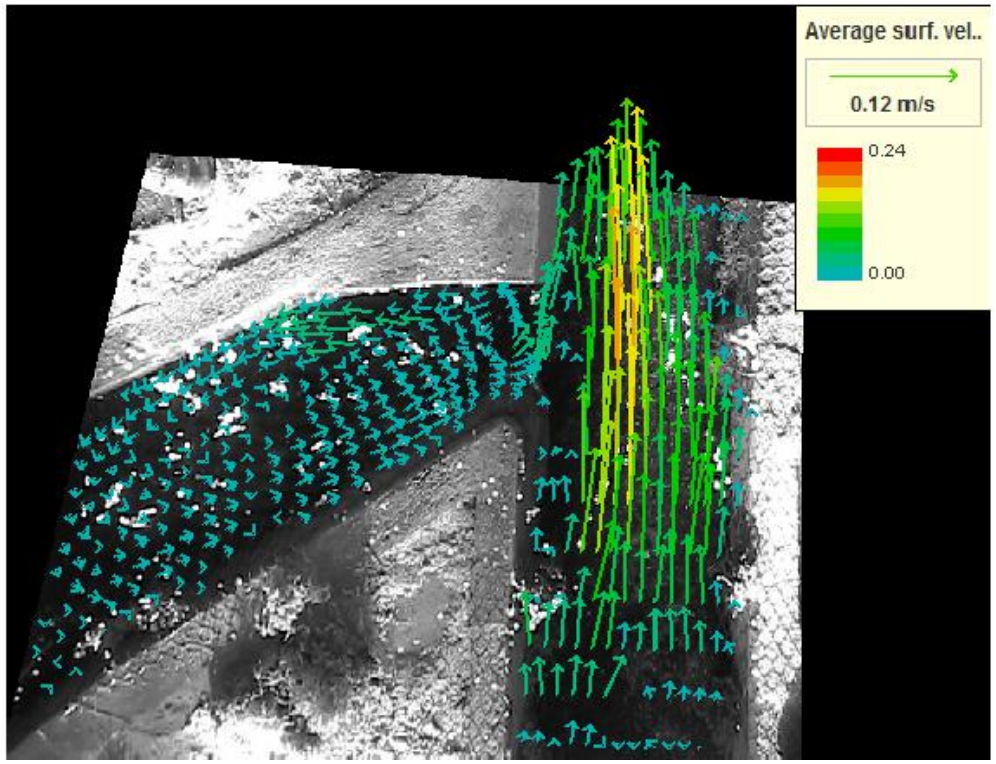
Instantaneous velocity field + correlation contours



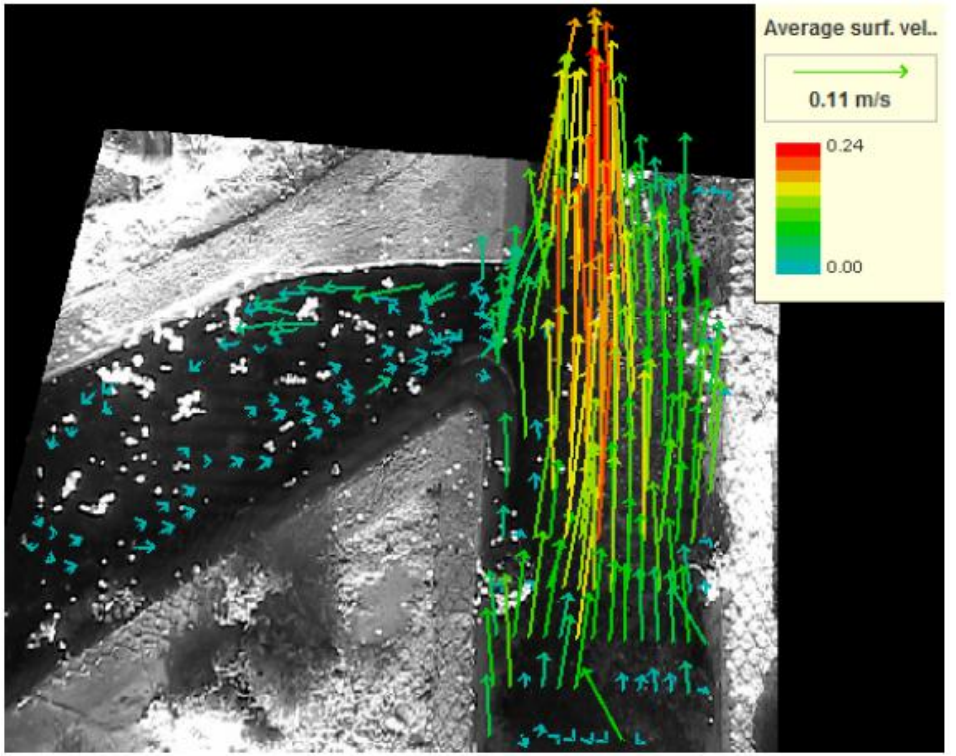
Laboratory: recirculation flow in a meander outlet

Time-averaged surface velocity field:

Without data screening



With data screening



Field: flood streamgauging from YouTube home movies

Flash-flood of the Gave de Cauterets River at Cauterets
(French Pyrenees, June, 2013)
Image from the movie posted by F. Lamouroux on YouTube

Field: flood streamgauging from YouTube home movies

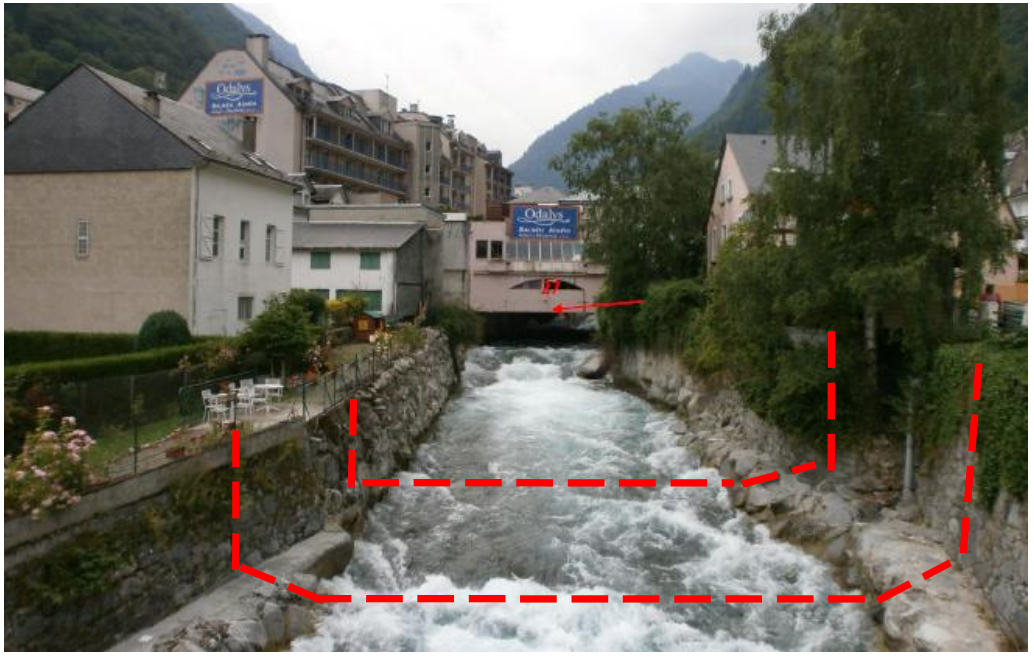
Collect of a valuable movie on YouTube

Position of the viewpoint using Google Maps / Street View

Contact the author, obtain agreement, check video metadata

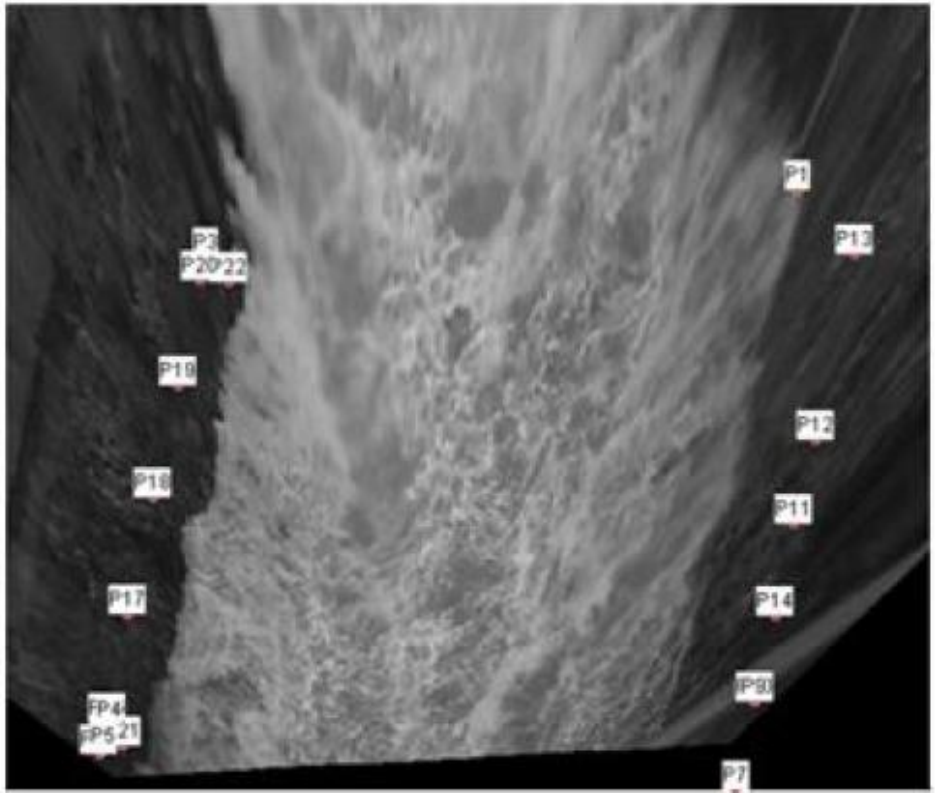
Achieve field topography survey : GRPs, bathymetry profiles, water level estimation

Then go with Fudaa-LSPIV...



Field: flood streamgauging from YouTube home movies

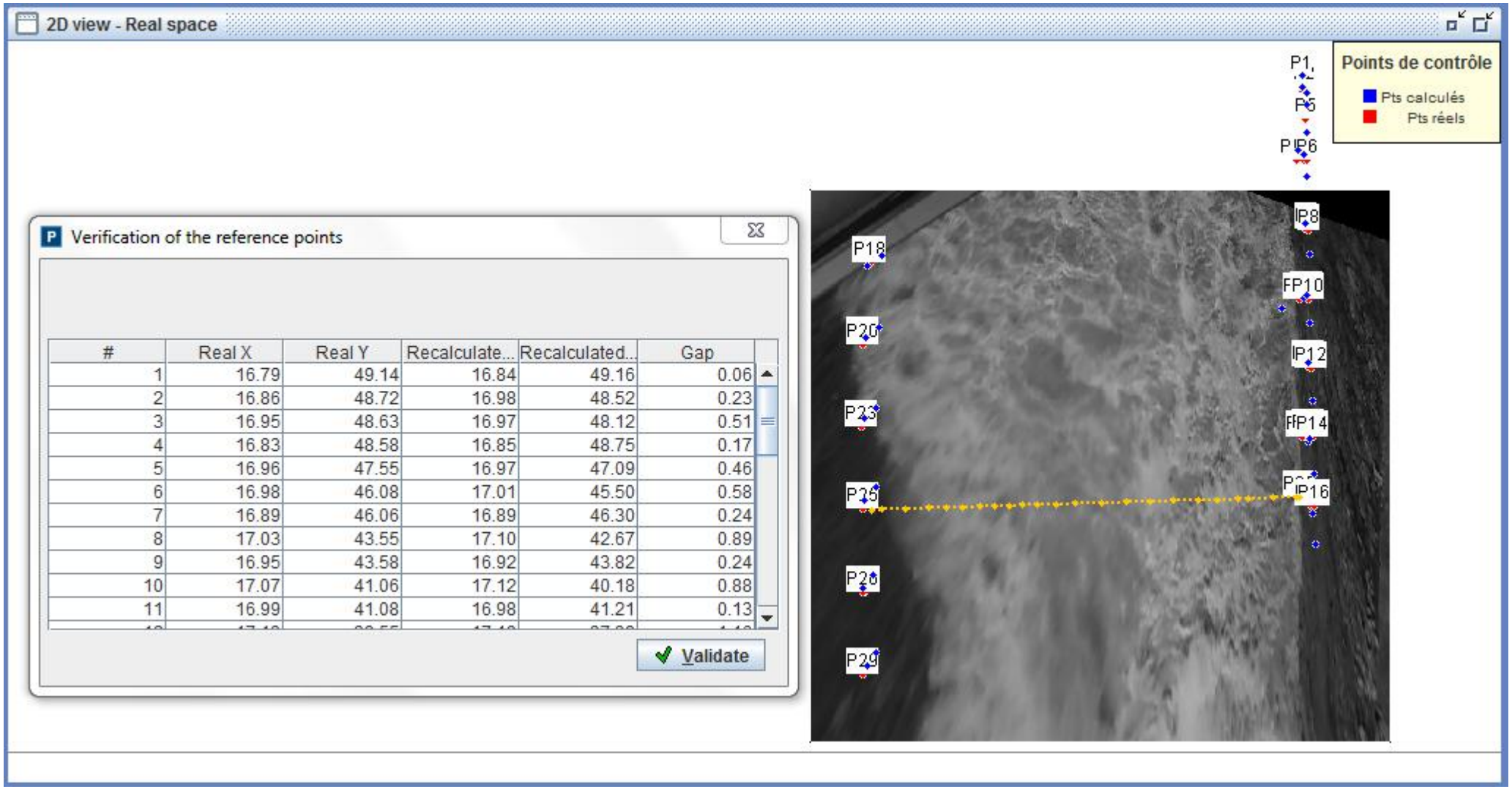
GRP positioning and image orthorectification



Field: flood streamgauging from YouTube home movies

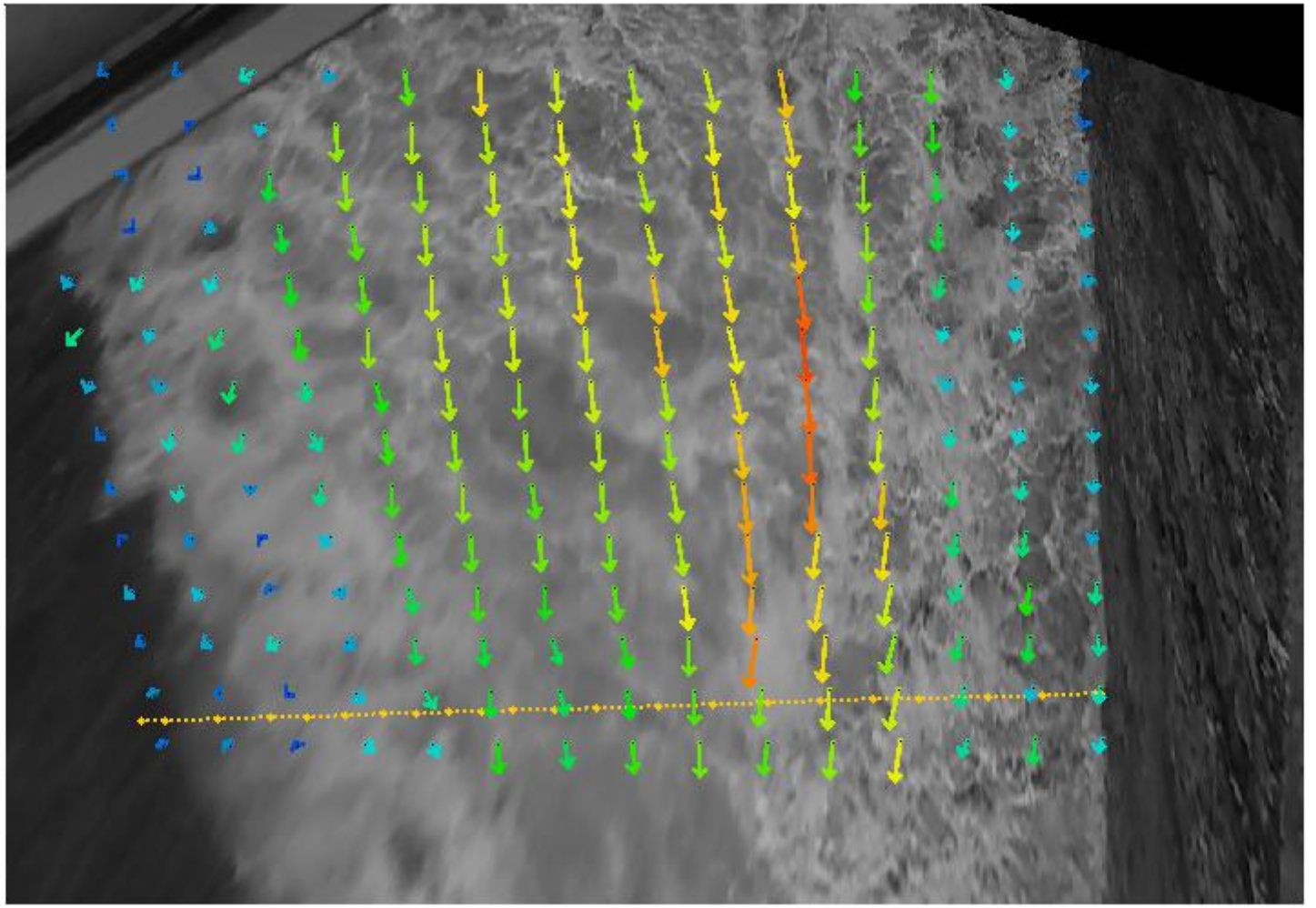
Verification of the accuracy of the orthorectification matrix:

Comparison of the real and computed positions of GRPs



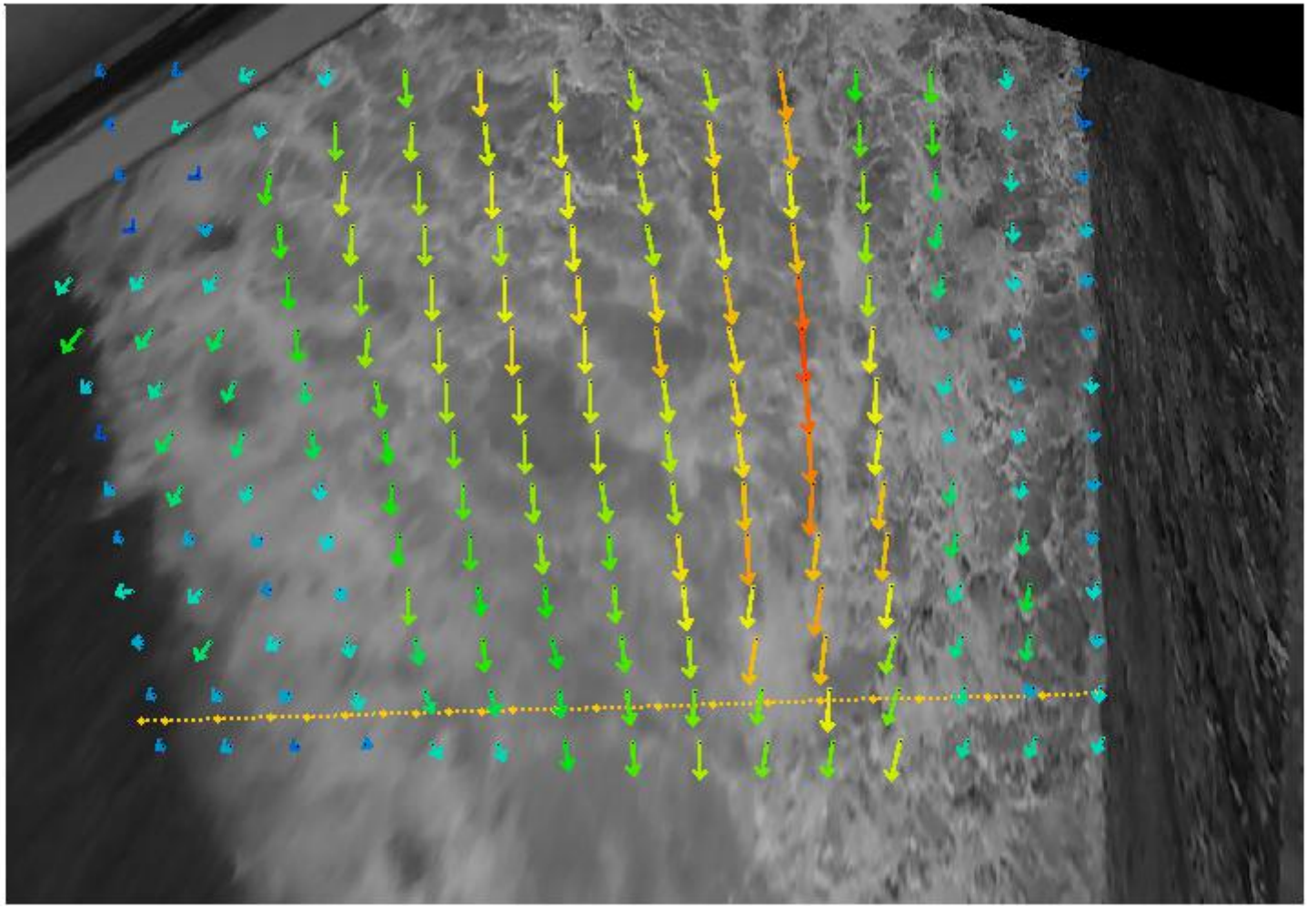
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #1



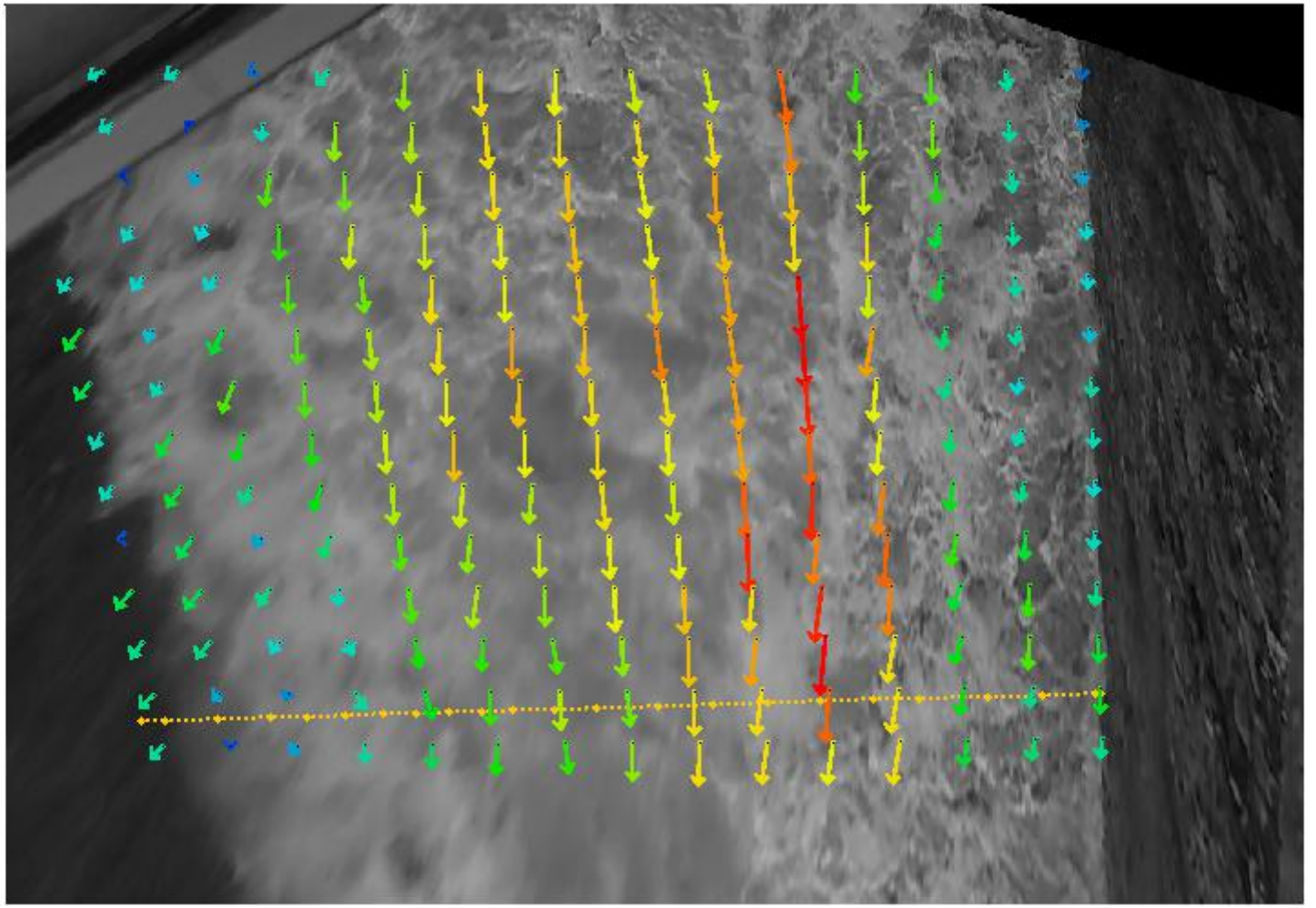
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #2



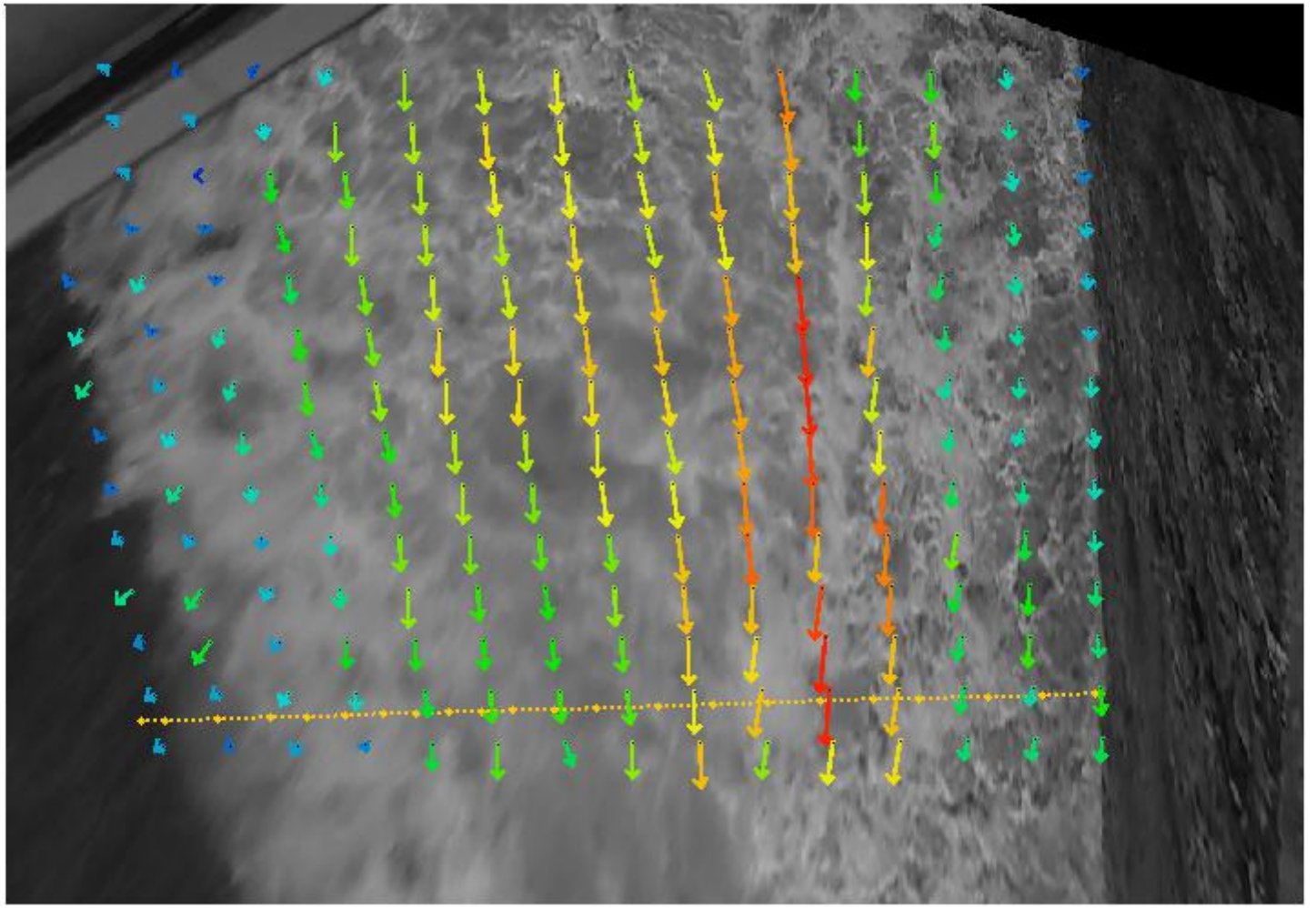
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #3



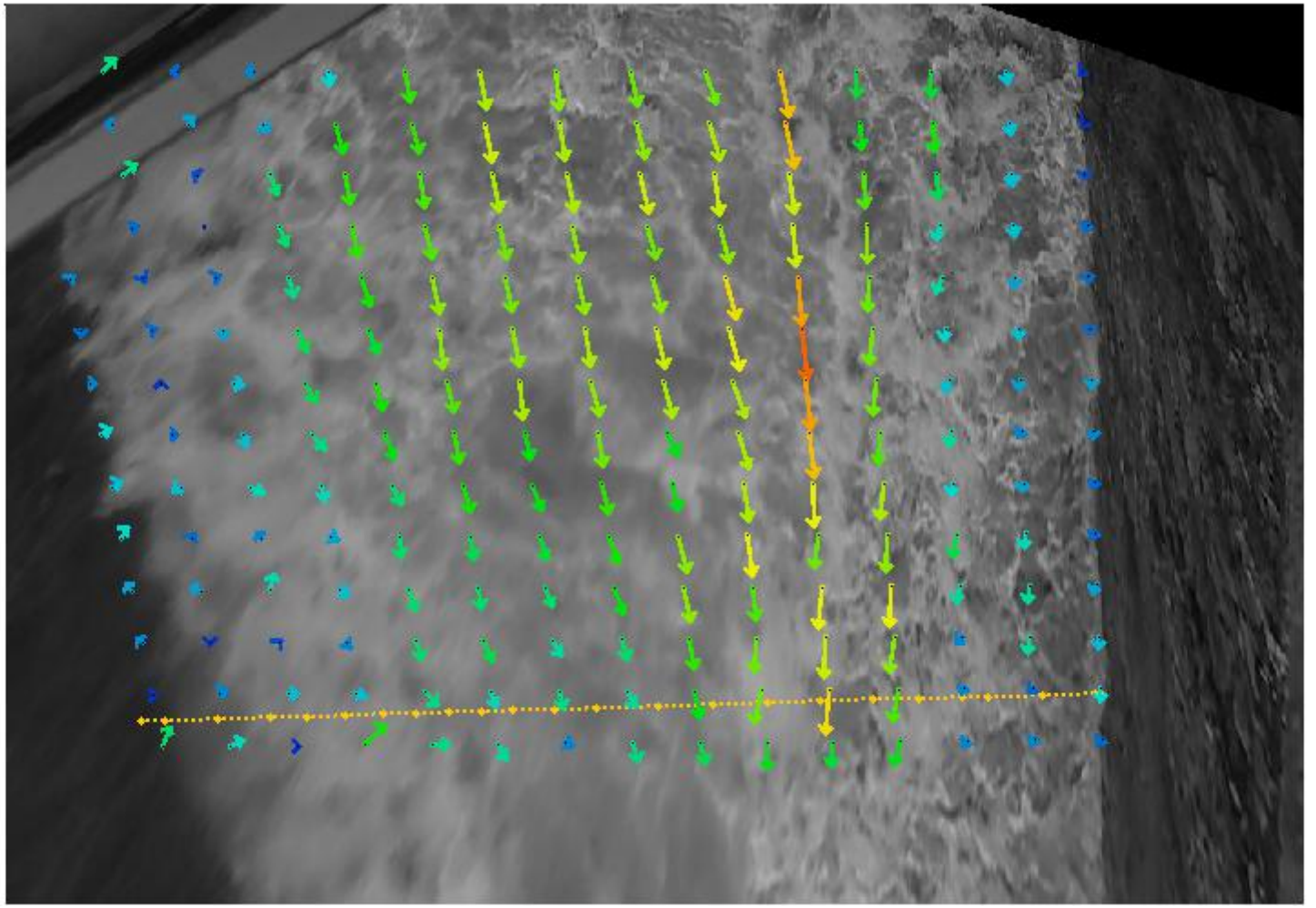
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #4



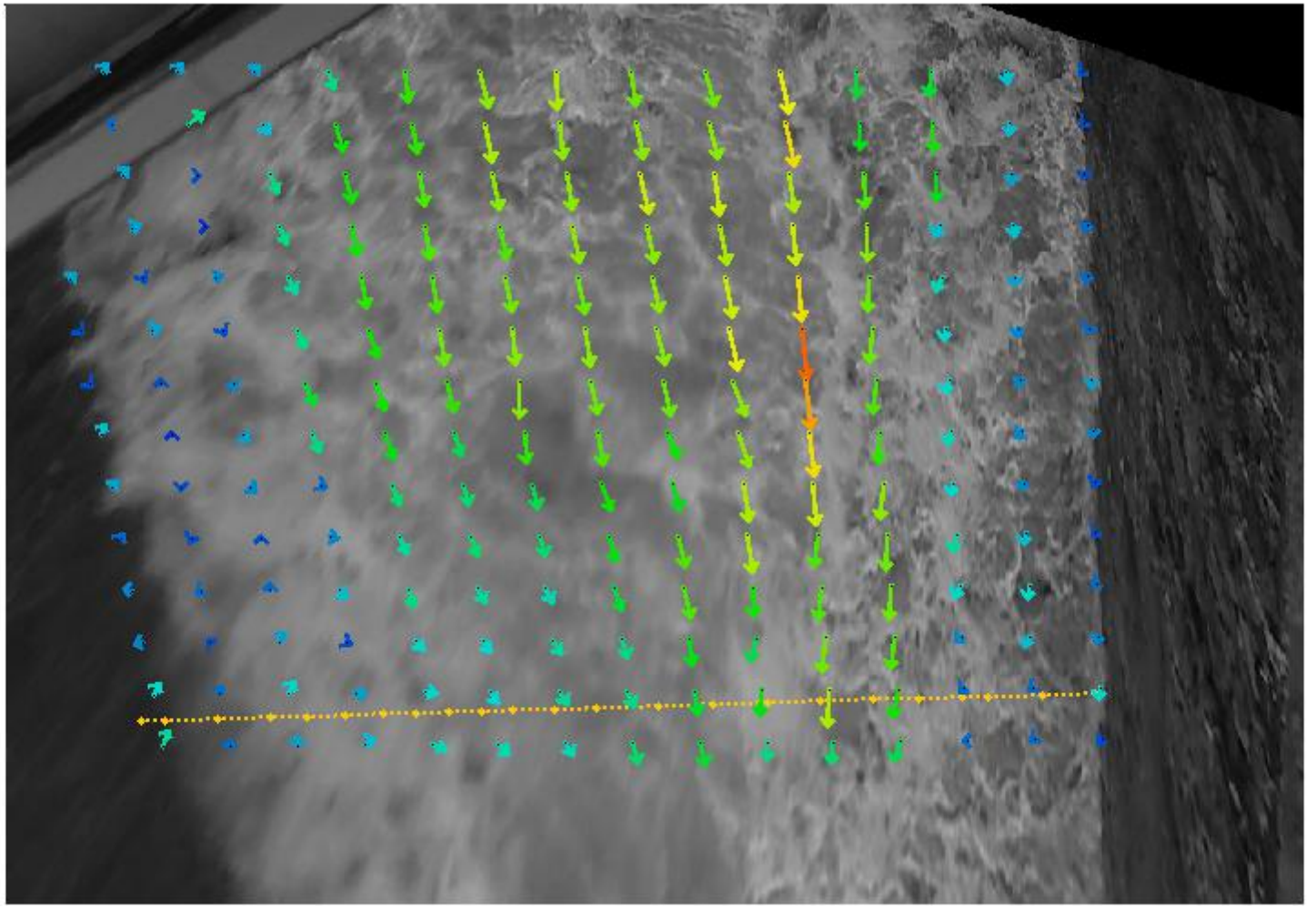
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #5



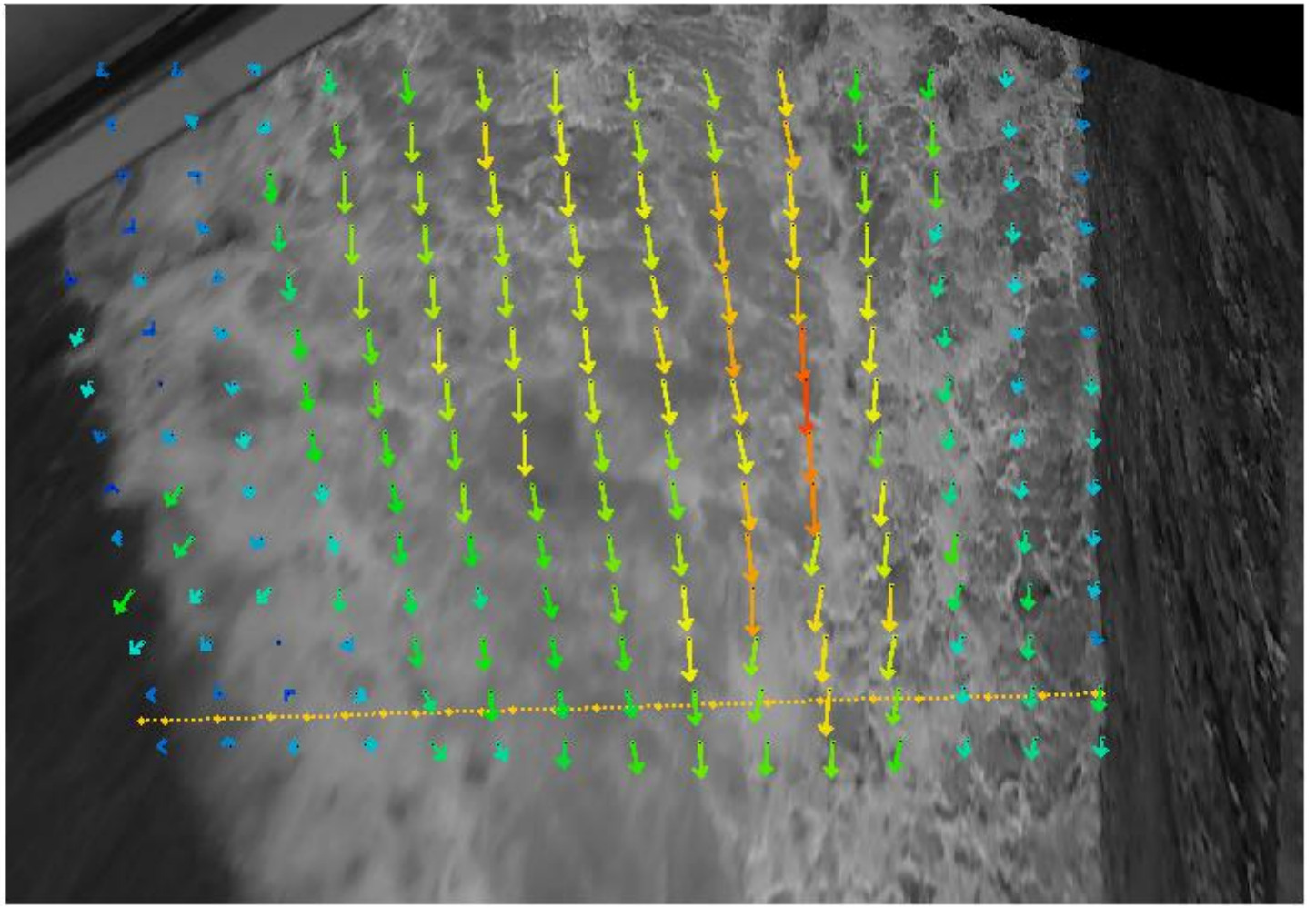
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #6



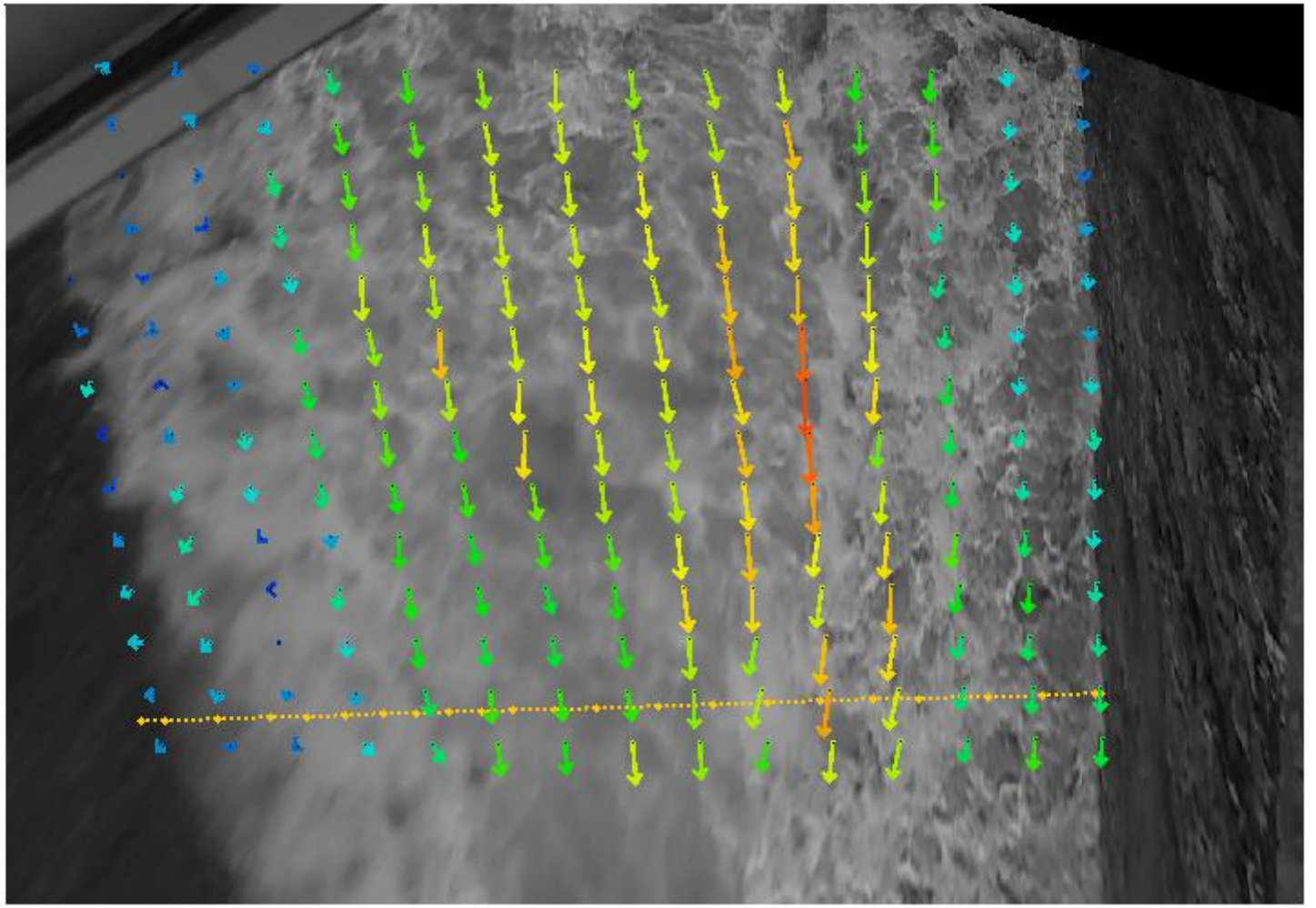
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #7



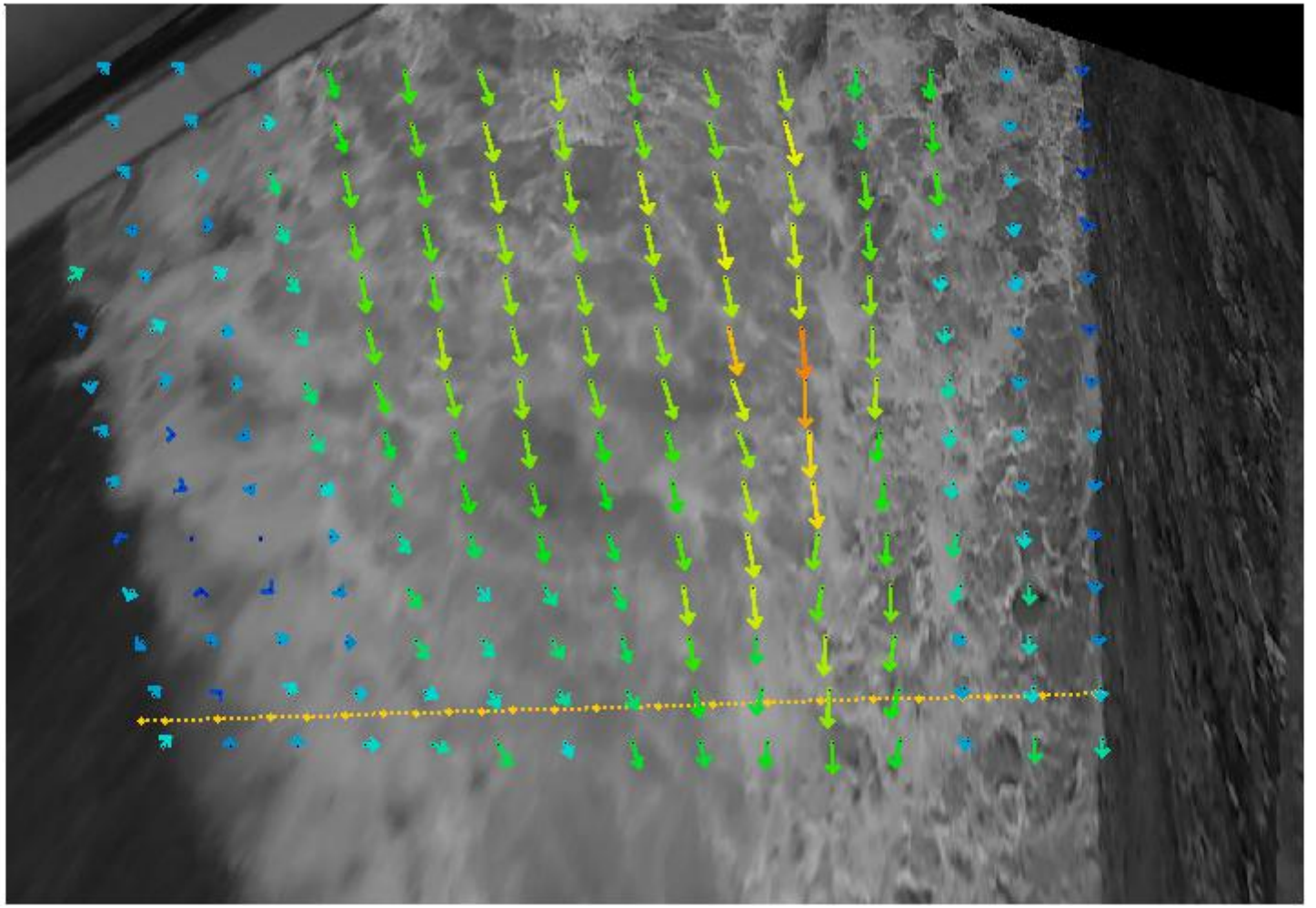
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #8



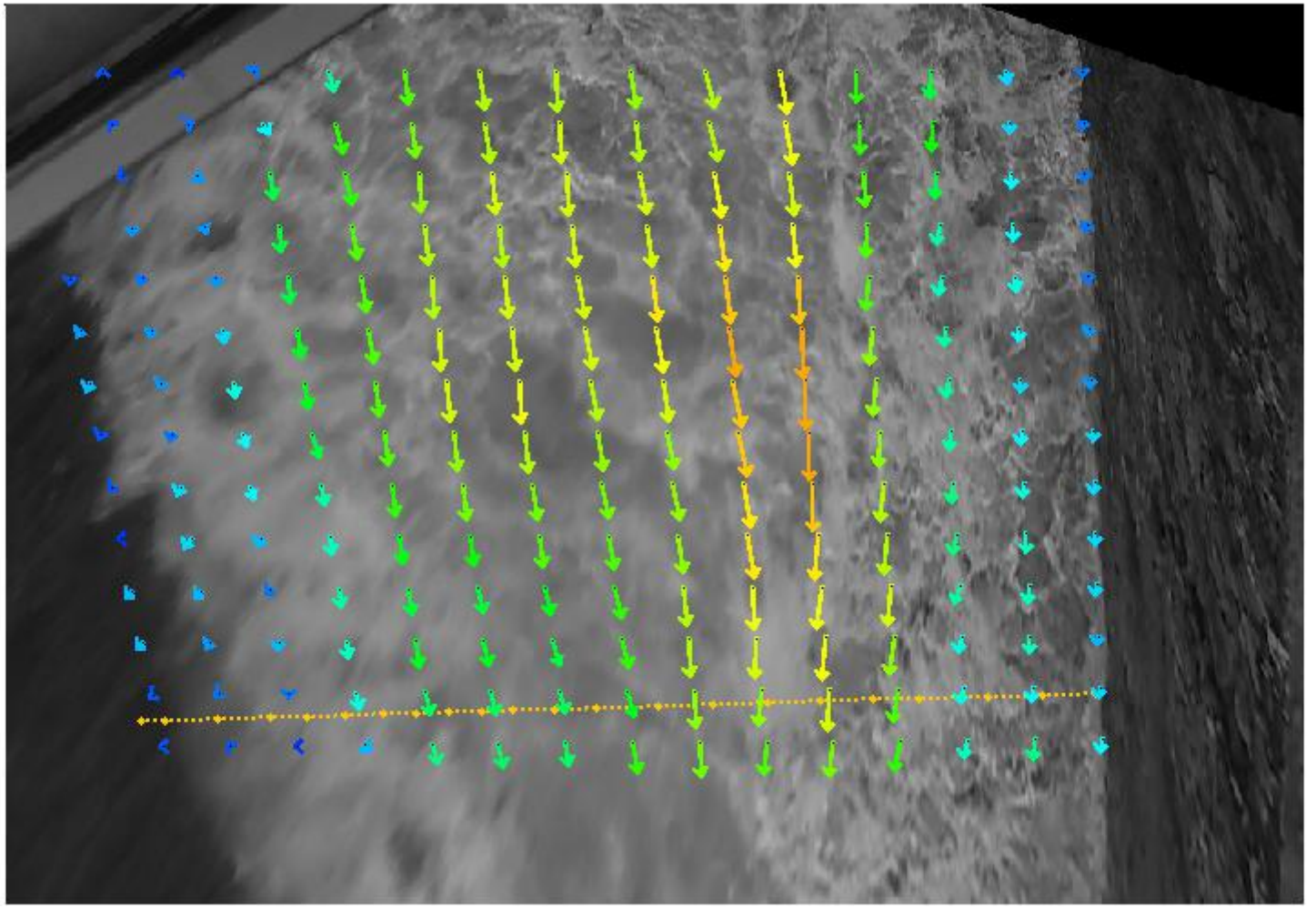
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #9

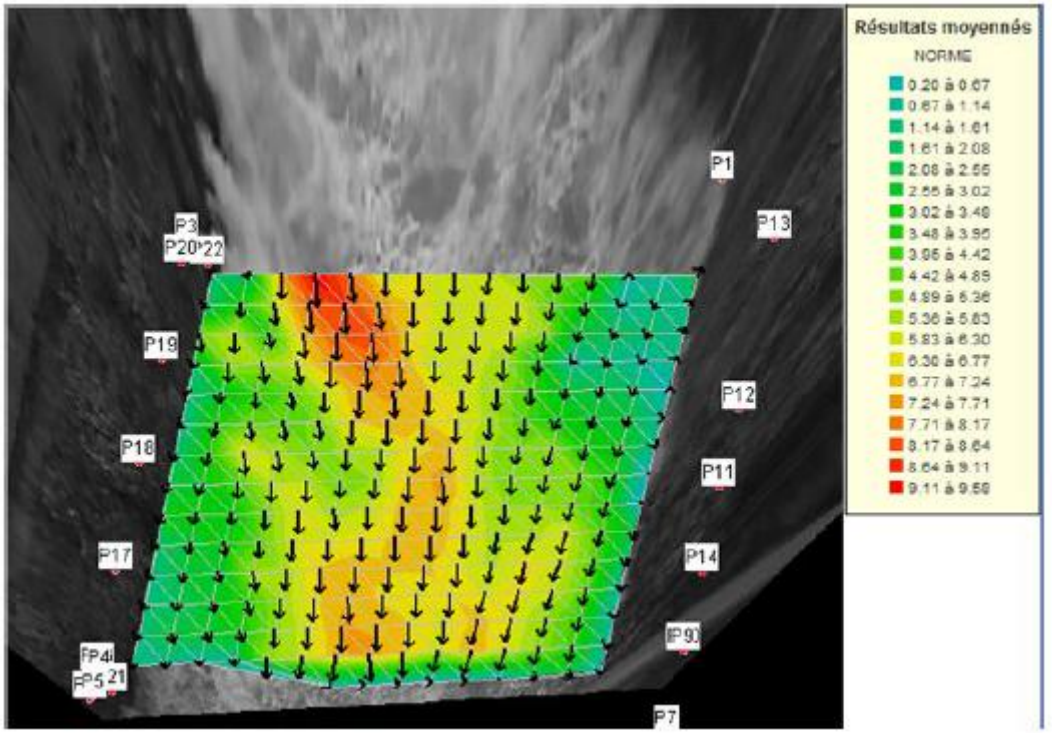


Field: flood streamgauging from YouTube home movies

Time-average velocity field



Field: flood streamgauging from YouTube home movies



Results:

Time-averaged surface velocity field

Discharge estimates computed across 3 different transects: close agreement

Main uncertainty: bed changes!

Table 1: LSPIV discharges for Cauterets

Cross-sectional profile	Discharge [m^3/s]	Estimated uncertainty	Departure to average
1	103	25%	+5%
2	94	25%	-4%
3	96	25%	-2%
Average	98	–	–

Conclusions and perspectives for Fudaa-LSPIV

- A free and easy software designed for LSPIV end-users
- French and English user manual and graphical interface

- Step by step image and data processing
- Visualization and exportation capabilities

- Interest for laboratory and field hydraulic applications
- Any suggestions for future improvements are welcome!

Thanks
for your attention!

Participative research on flash-flood observation using home movies from video sharing platforms
(Le Boursicaud et al., in revision, Hydrol. Processes)

ANR FloodScale Project (2012-2015)

Simplified procedure and public information for volunteering flood observers and flood chasers

http://floodscale.irstea.fr