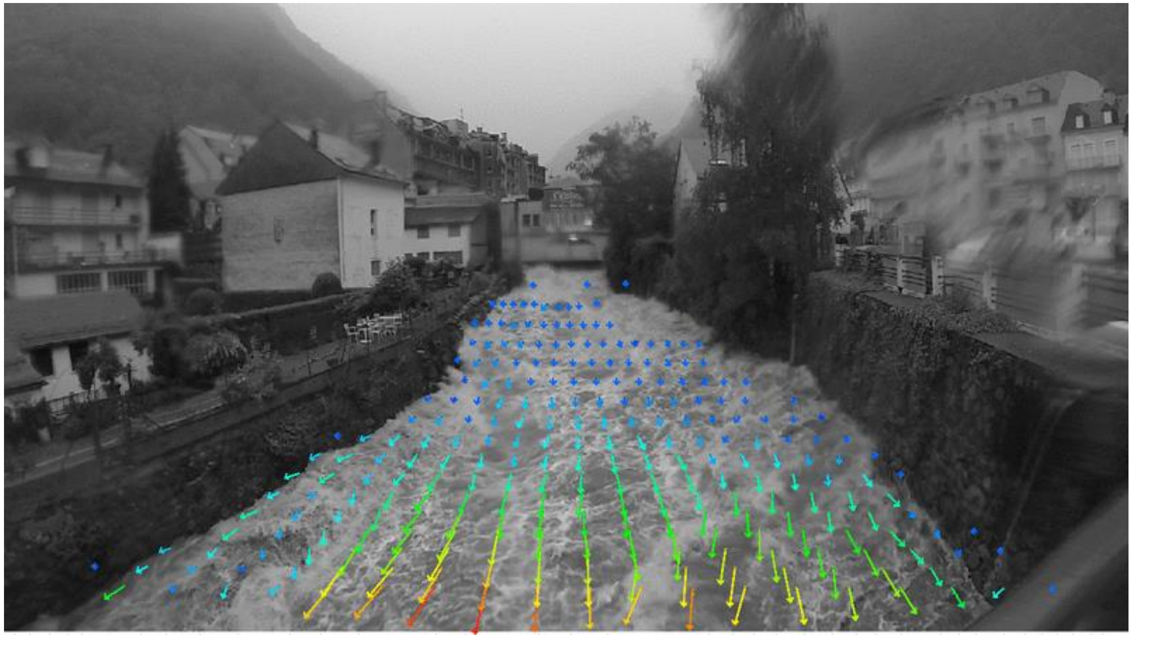
October 2022

Video-based discharge measurements using Fudaa-LSPIV



Jérôme LE COZ
INRAE, UR RiverLy, Lyon, France

INRAE

River hydraulics

Video-based hydrometry

Three main types of applications:

Discharge measurements

Automated stations

YouTube

debris flow - 22 août 2011 - Crue torrentielle à Saint Julien

Alexandre MODESTO

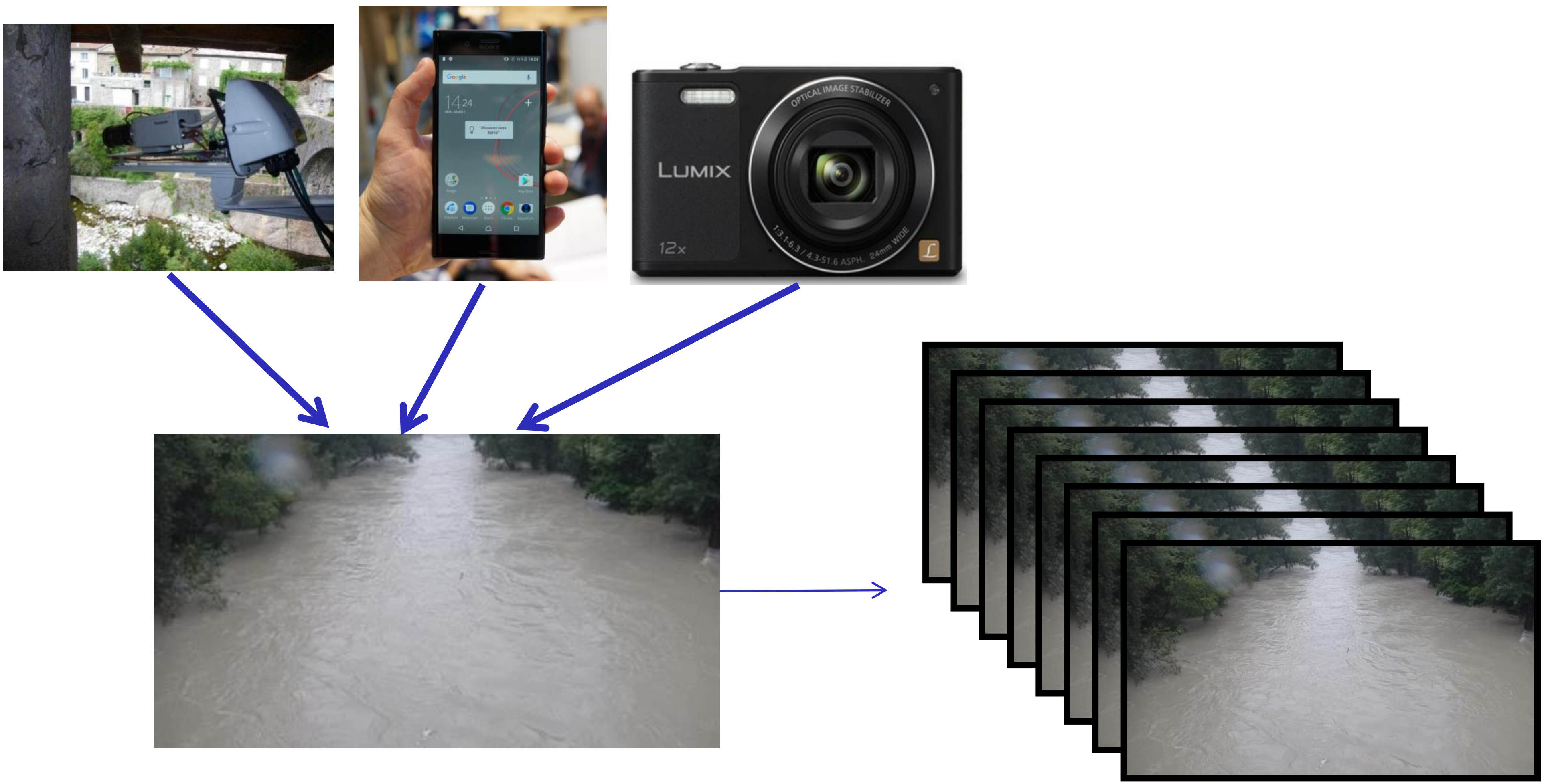
561 k vues

Post-flood estimates

Deployment methods

Any type of camera may suit

Image resolution may be a problem for far-field tracers from low-angle viewpoints



Deployment methods

The higher the viewpoint the better

Remotely controlled platform on top of a 10-m high mast

Biodegradable cornstarch chips may be added as tracers (not needed in flood conditions usually)

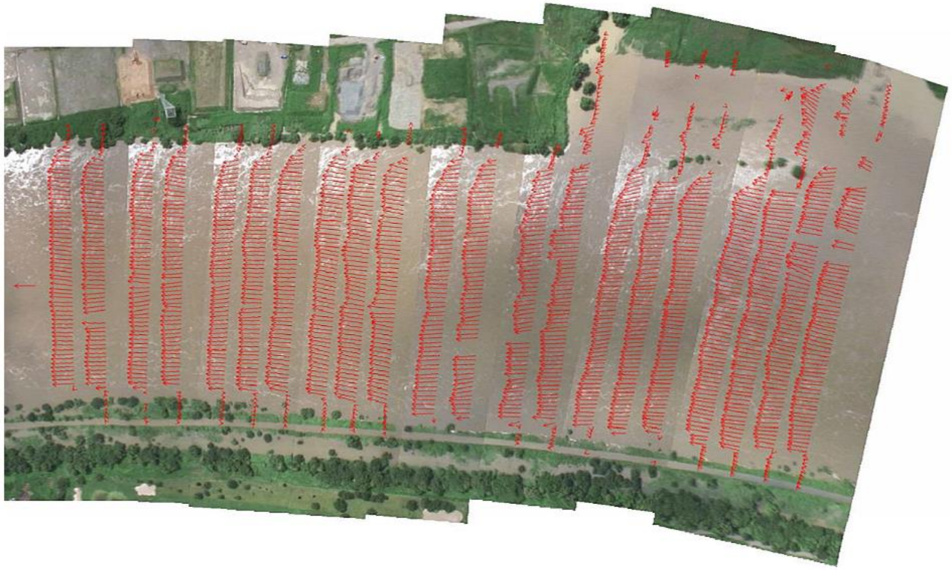
Deployment methods

UAV (Unmanned Aerial Vehicles, drones)

EDF experiments, from Alex Hauet

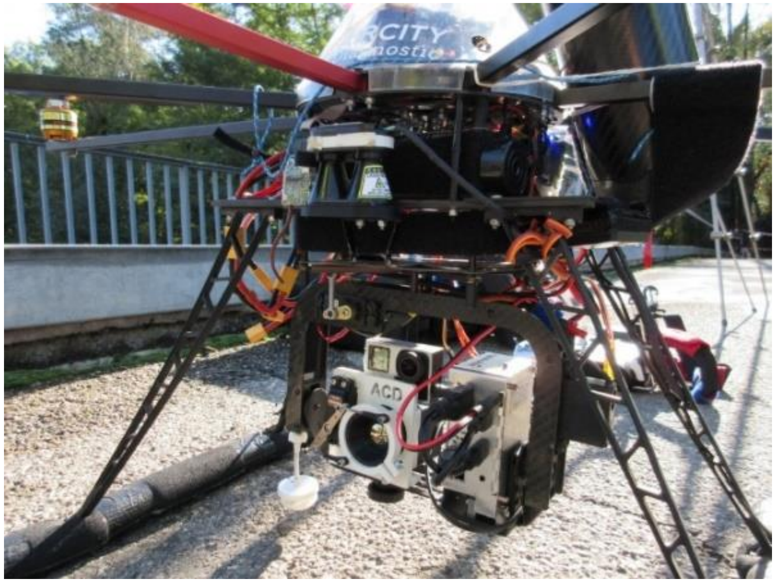
Helicopters…

Satellites…

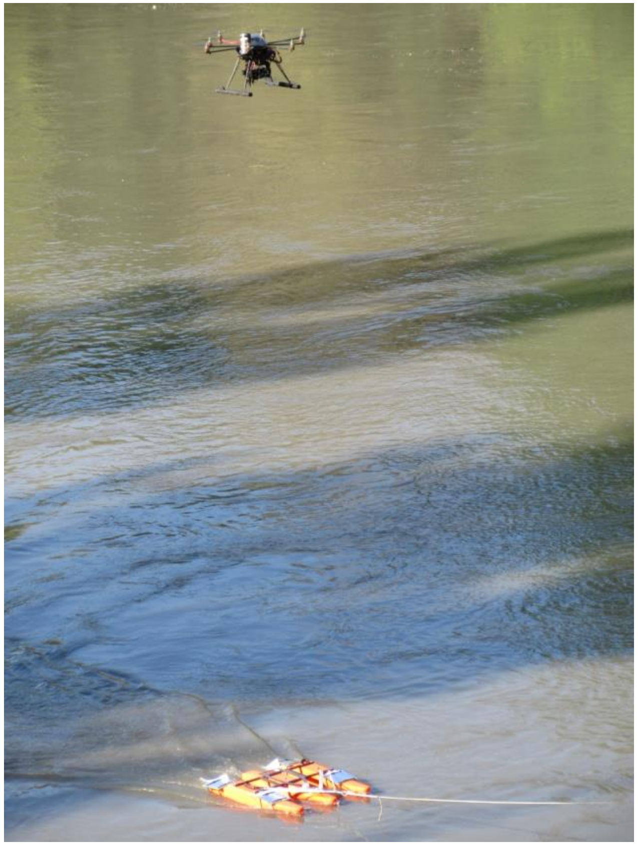


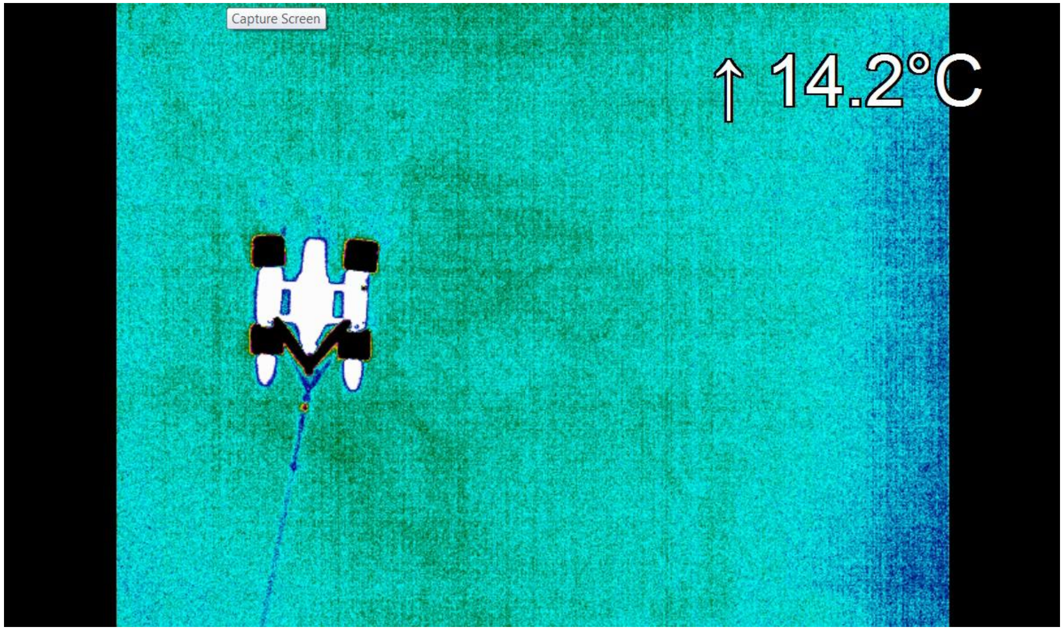
2007 Yodo River flood, Fujita Lab., Japan

Deployment methods



Thermal Infra-red (TIR) camera from high-grade drone





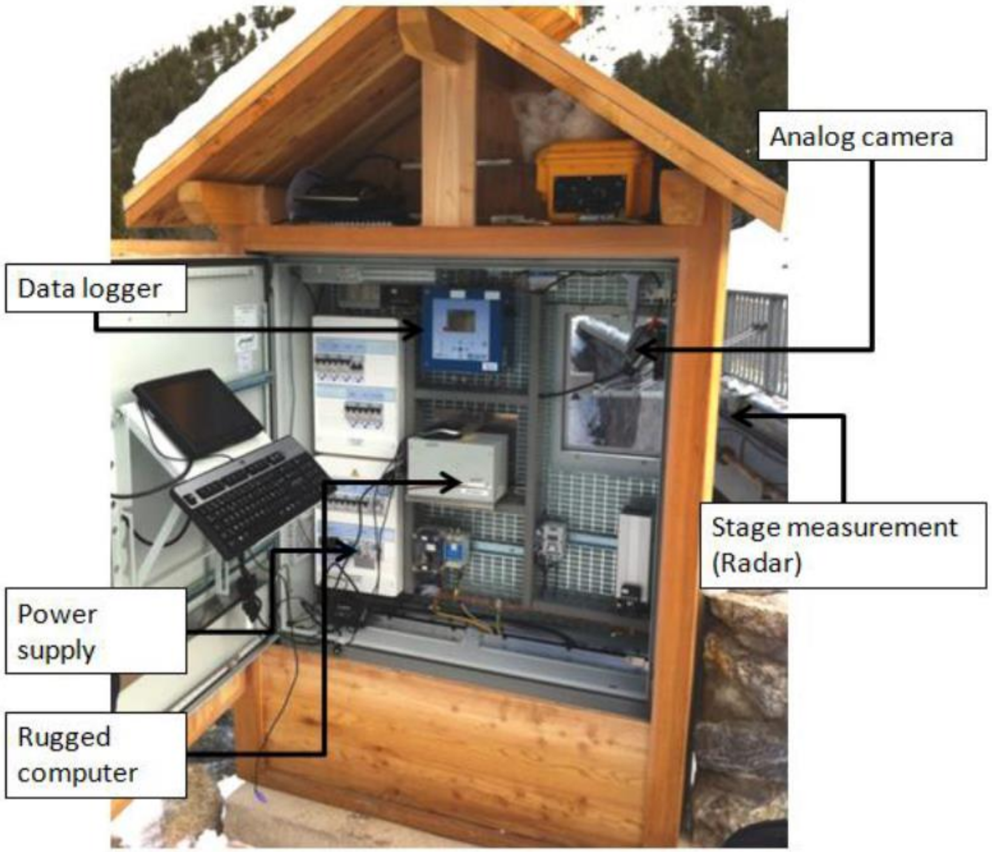
EDF experiments, from Alex Hauet

Deployment methods

Automated stations

- ✓ Flood gaugings at high temporal resolution (5 min)
- ✓ Conventional rating curves and water level recorder

Video-based gauging stations operated by EDF

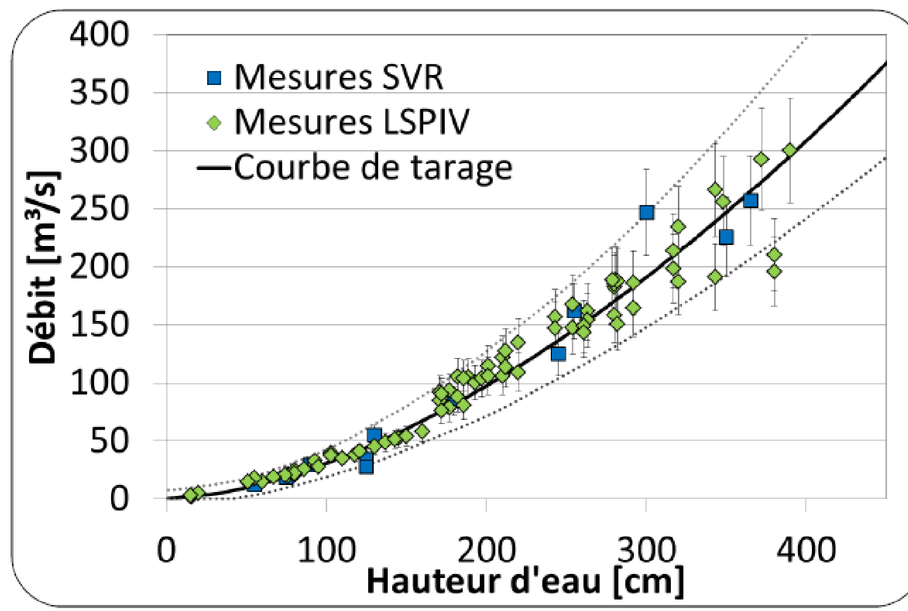


Deployment methods

Automated stations

- ✓ Flood gaugings at high temporal resolution (5 min)
- ✓ Conventional rating curves and water level recorder
- ✓ On-site data storage and (optional) telemetry
- ✓ Night measurement tests: lightfinder and FLIR cameras

Camera and radar level gauge
Auzon at Vogüé-Gare (INRAE)



Rating curve built with SVR and LSPIV gaugings after 3 years

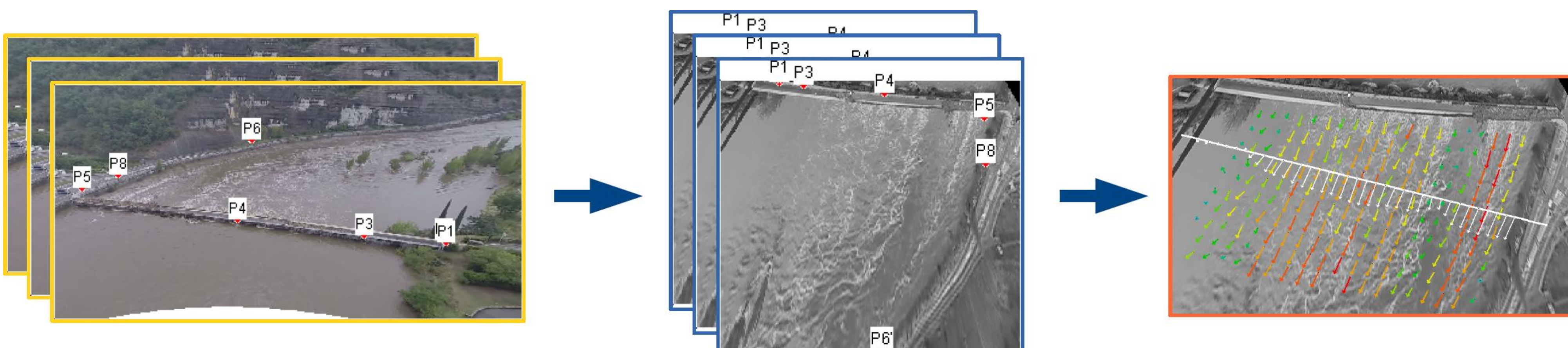
Deployment methods

Drone video found on YouTube

Comparison with gauging station

http://www.ardechevideo.com/

Water Level (m)	LSPIV discharge (m^3/s)	Q deviation (%) Gap (30 min) Qref. : 880	Q deviation (%) Gap (60 min) Qref. : 790
94.5	1053	+16	+25
94	913	+3.6	+13
93.5	795	-11	+0.6



Fudaa-LSPIV free software

Co-development EDF, INRAE and implementation by DeltaCAD

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

Sharing the method and software

- Free release, GUI is open-source (GPL)
- 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

Contact

- fudaa-lspiv.dev@lists.irstea.fr

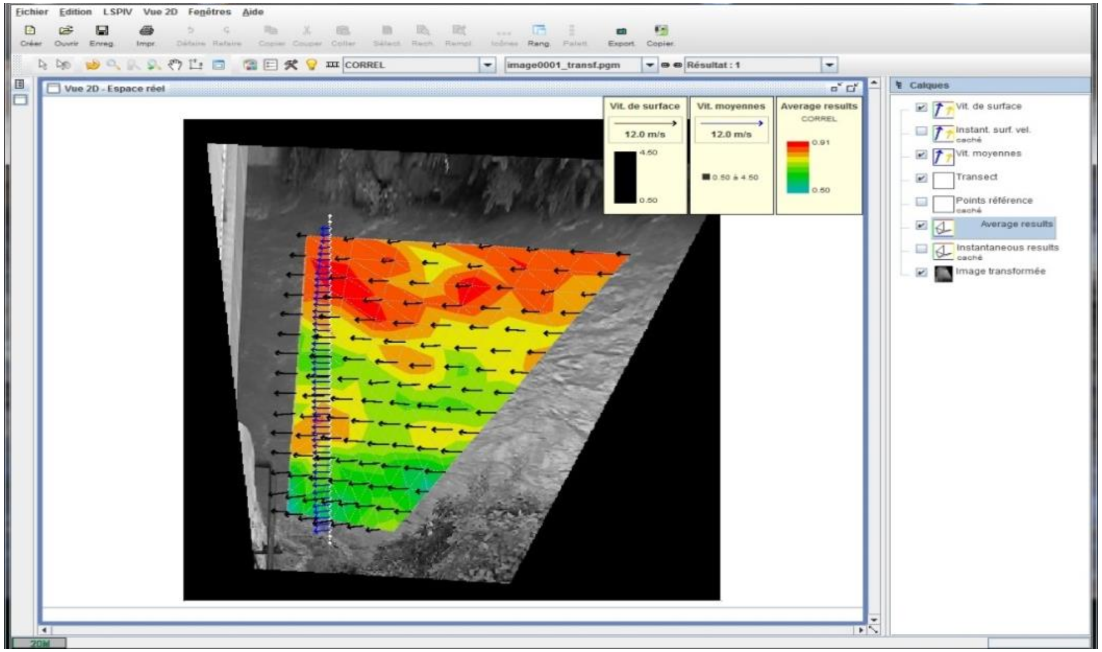


Image based river discharge methods

Main steps

1. Record image pairs with known time intervals
2. Ortho-rectify images
3. Compute surface flow velocities (raw, filters, average)
4. Discharge computation

Step 1. Record image pairs / sequence

- Accurate time intervals between image pairs
- Flow tracers should be visible, dense and representative of flow
- Lighting: avoid reflections, shadows, glittering, etc.

✓ Fixed camera (otherwise camera movement must be corrected)

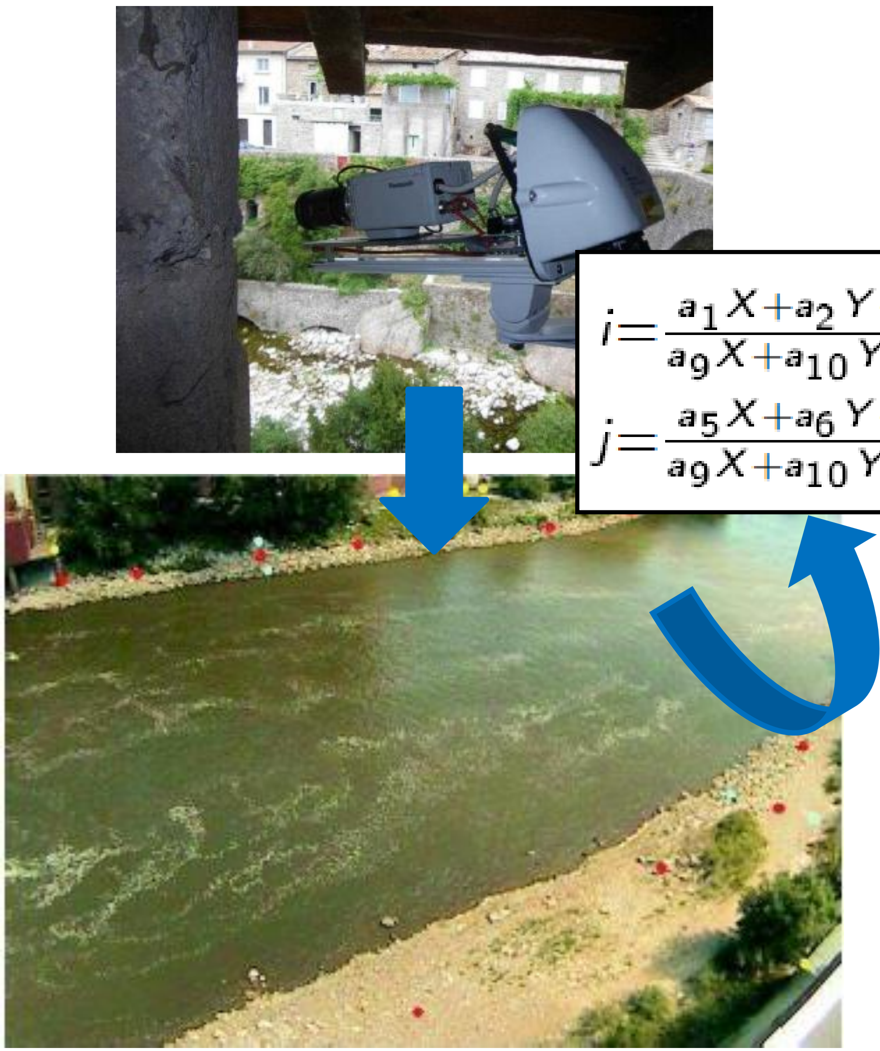
✓ Rectilinear lens (otherwise fish-eye effect must be corrected)

✓ Both banks and fixed objects visible

✓ A few seconds may be enough

Step 2. Image transformation / orthorectification

Implicit camera calibration using fixed ground reference points (GRPs)



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

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

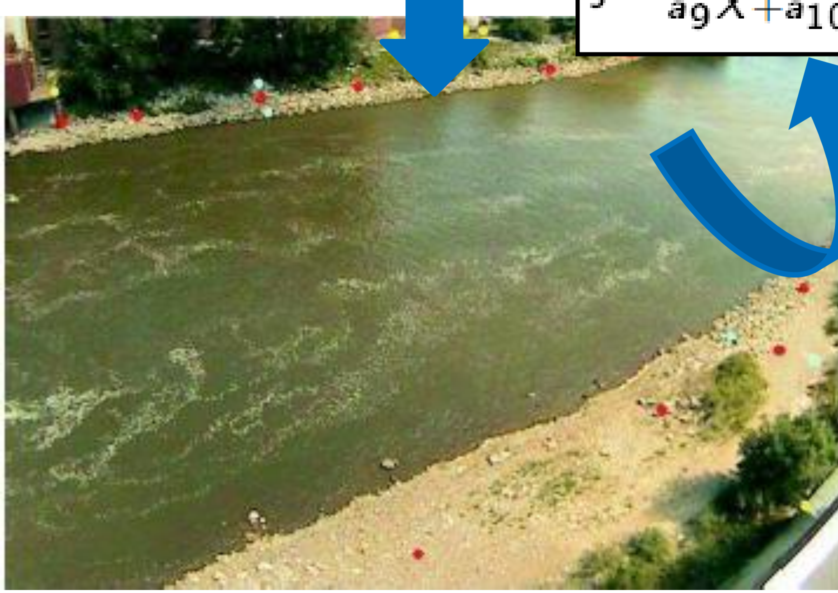
Alternative approach: Explicit camera calibration

Camera position, angles, focal distance, etc. are estimated explicity. Then orthorectification coefficients are computed.

Step 2. Image transformation / orthorectification

Orthorectification of gray-scale images: plane-to-plane projection

Rectilinear lens with negligible distortion, perspective effect only



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

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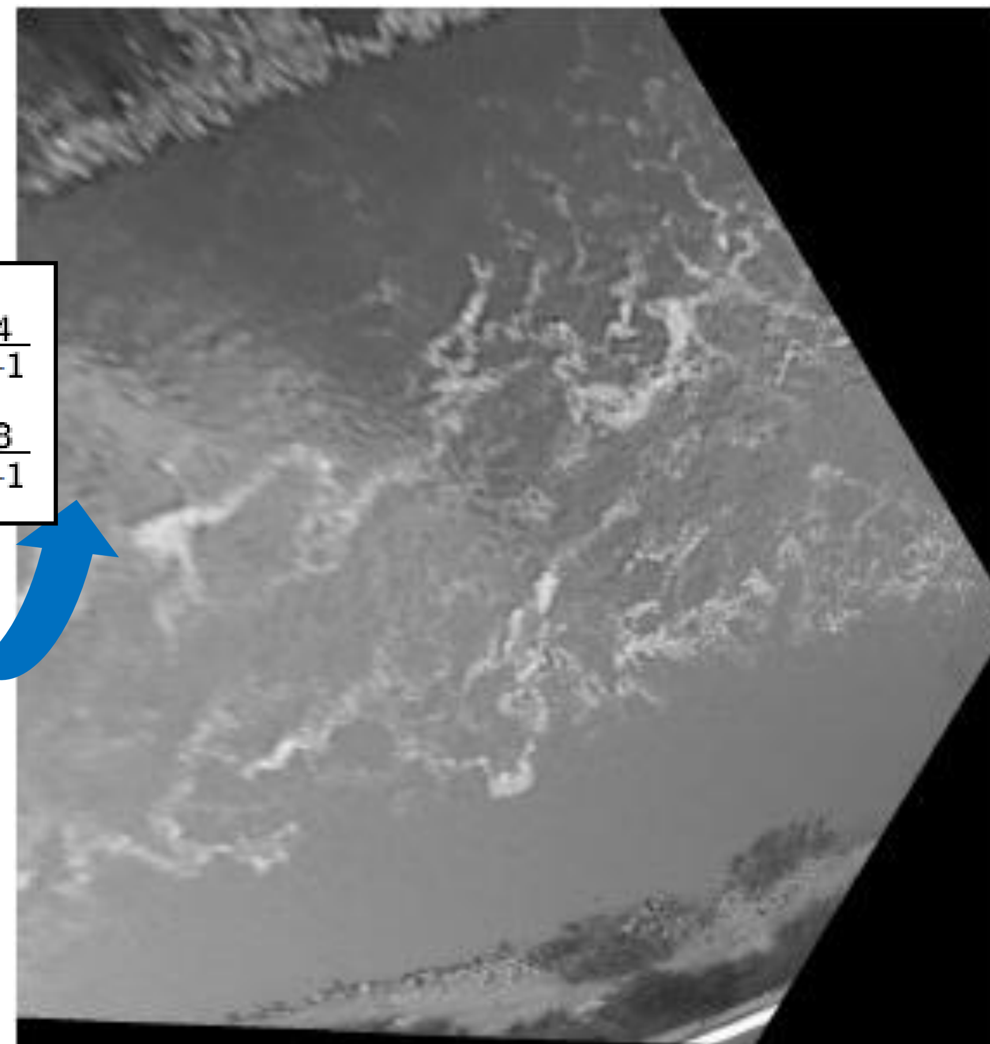


Image transformation options

2D orthorectification

- At least 4 GRPs

3D orthorectification

- At least 6 GRPs

Scaling

- No GRP

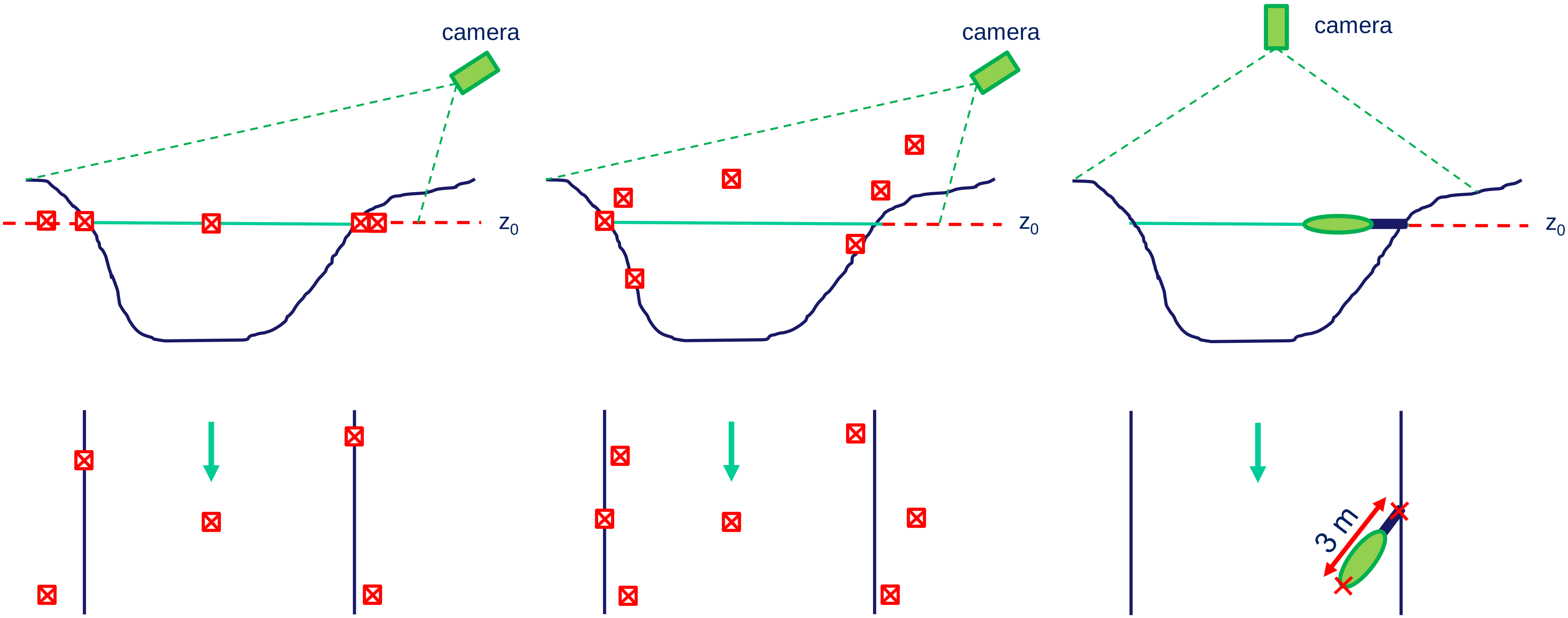


Image transformation options

3D orthorectification

- Oblique viewpoint
- At least 6 GRPs
- Not aligned
- Different z_{GRP} covering the range of water elevation

Water level can vary (cf. stations)

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

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

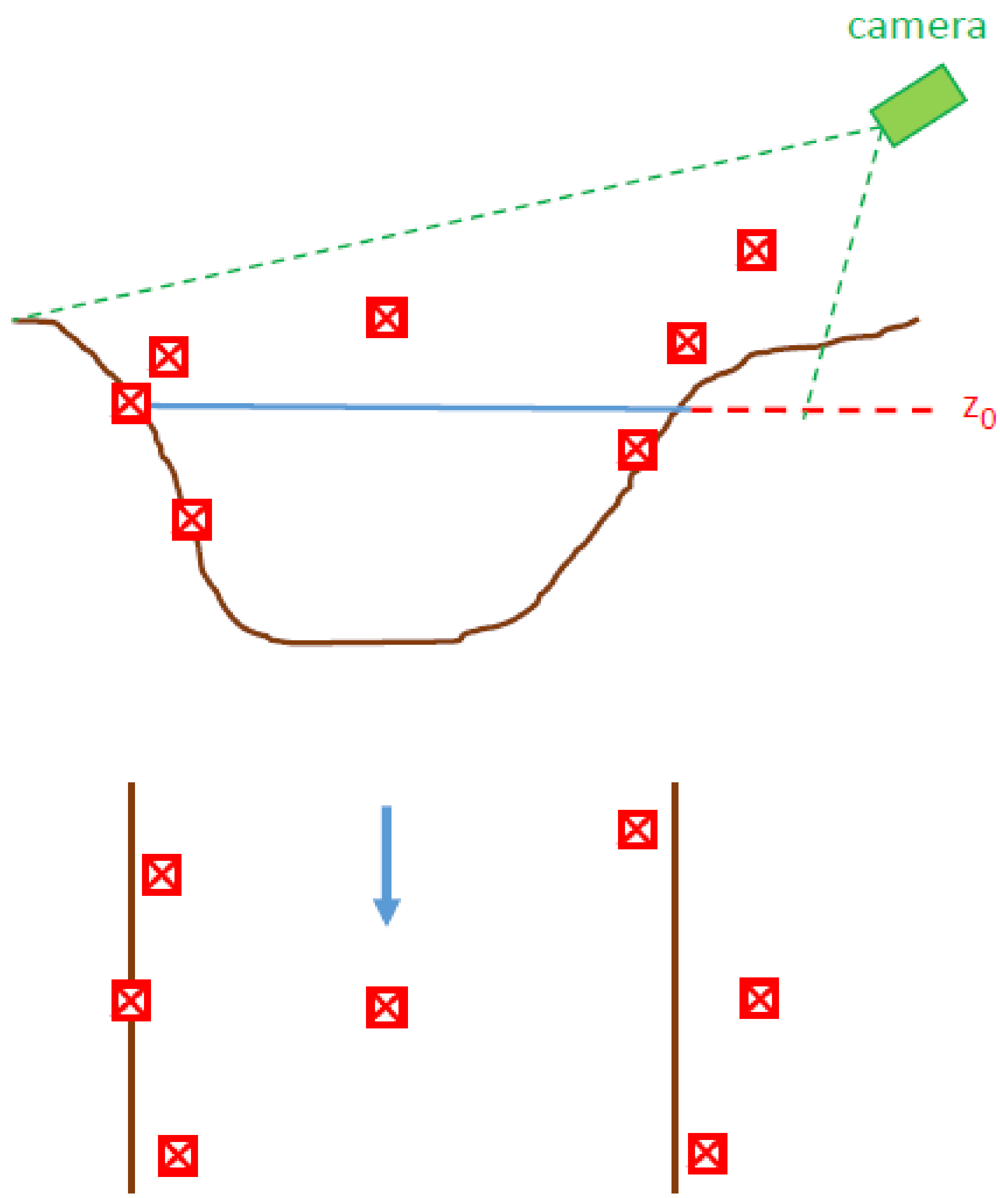


Image transformation options

2D orthorectification

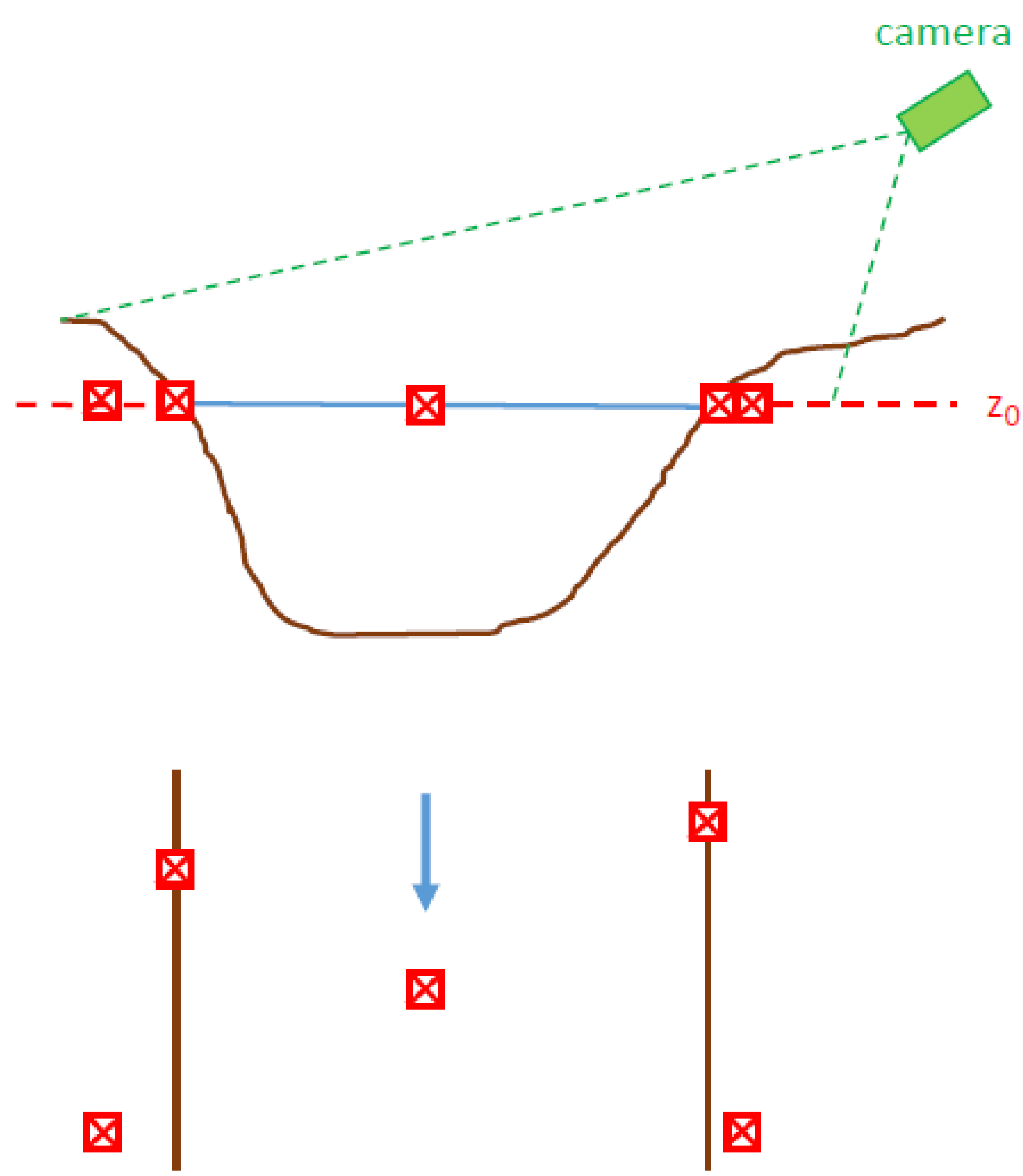
- Oblique or vertical viewpoint
- At least 4 GRPs
- Not aligned
- $z_{GRP} = z_0$ for all GRPs

with z_0: water elevation

Water level must be constant

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

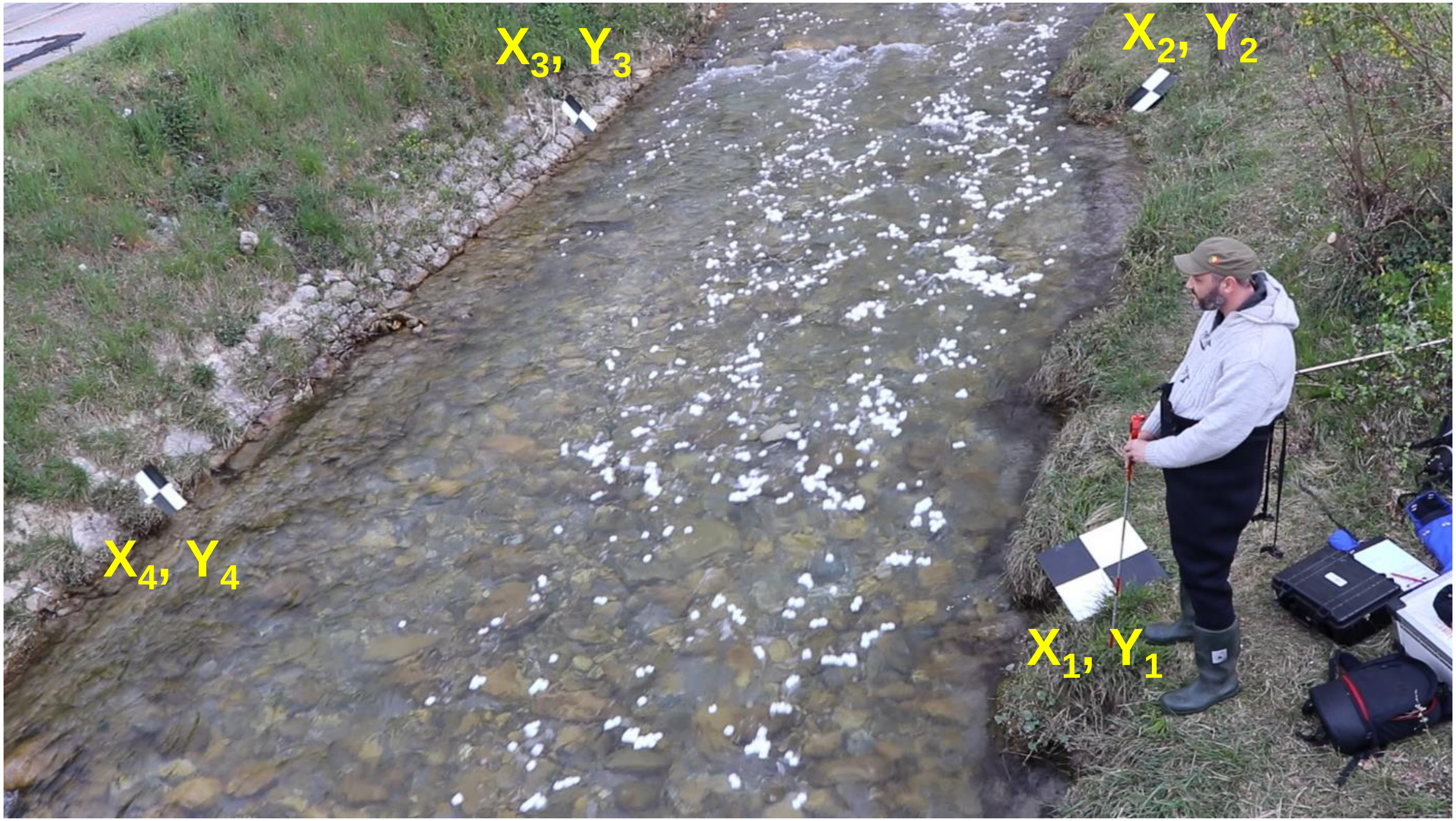
$$j = \frac{a_5 X + a_6 Y + \cancel{a_7 Z} + a_8}{a_9 X + a_{10} Y + \cancel{a_{11} Z} + 1}$$



2D orthorectification

At least 4 reference points at free-surface elevation:

Option 1: measure the XY coordinates



2D orthorectification

At least 4 reference points at free-surface elevation:

Option 2: measure 5 distances between the reference points

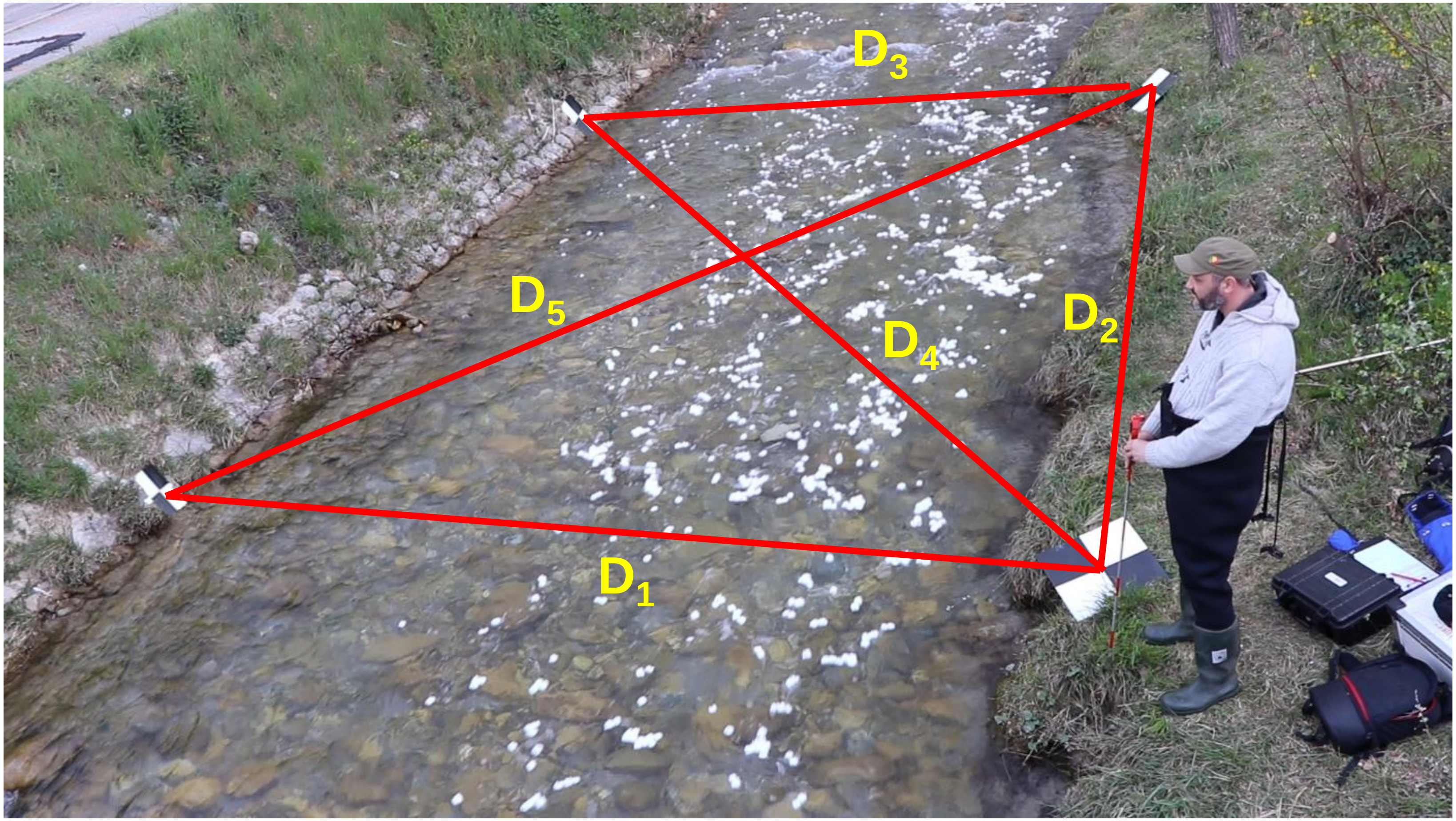


Image transformation options

Scaling

- Vertical viewpoint
- No GRP
- At least one segment of known length, close to water elevation

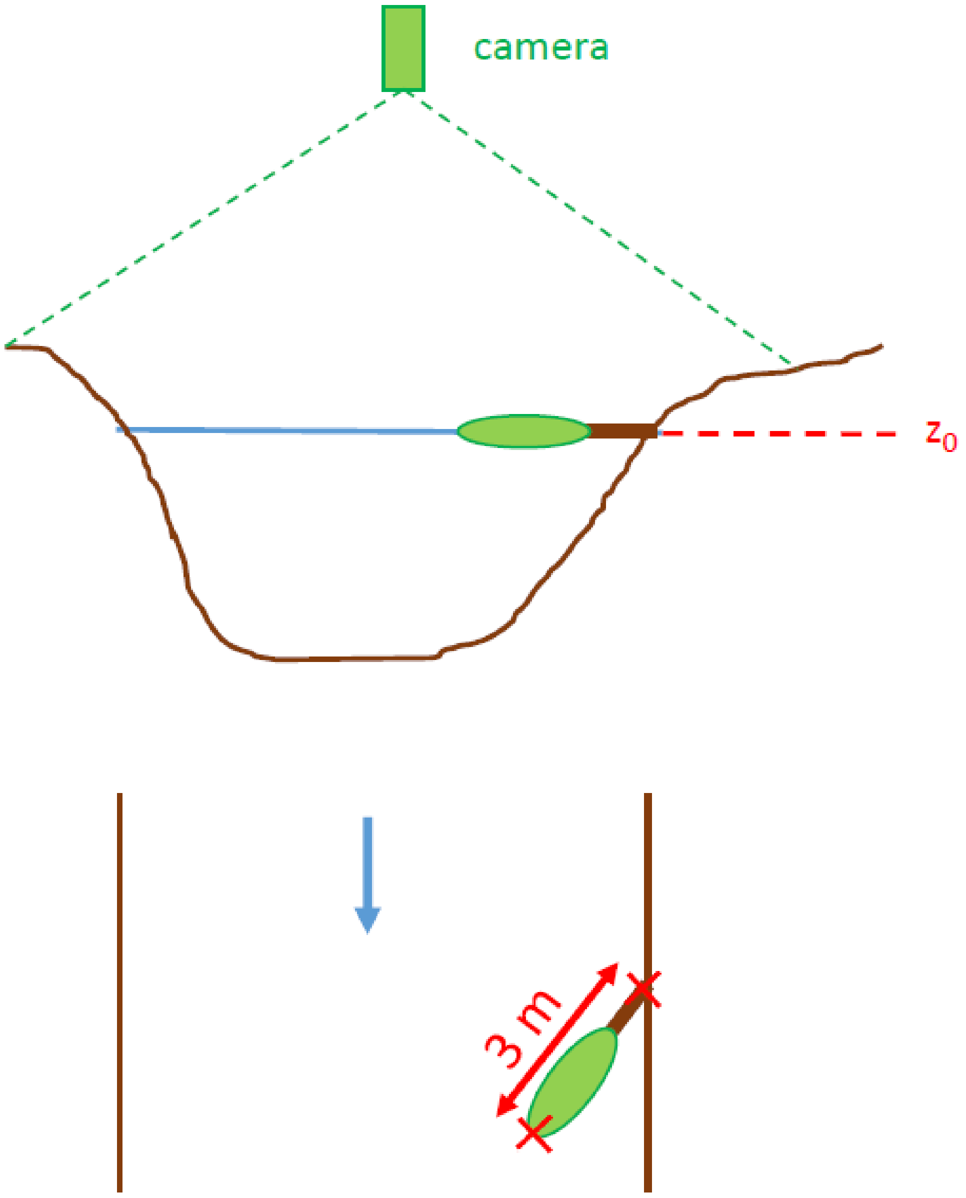
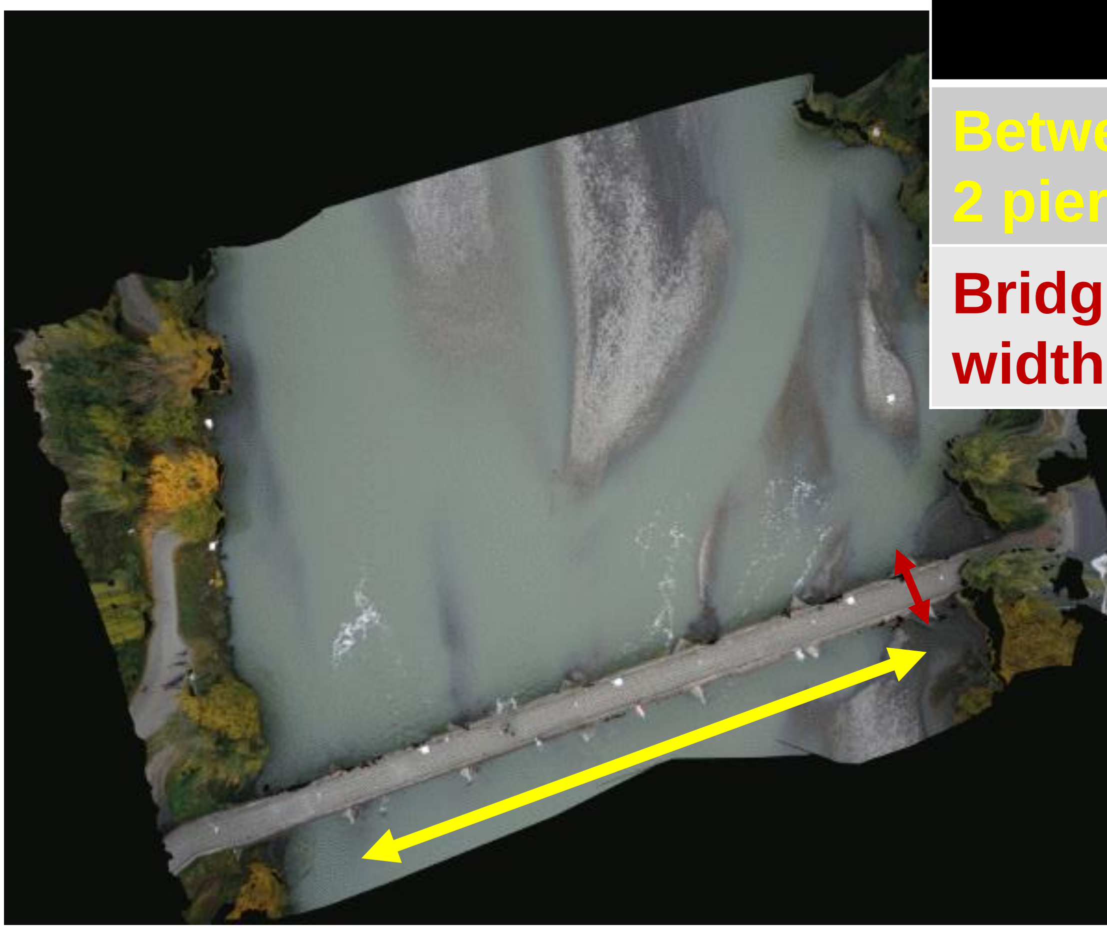


Image transformation options: Scaling

Example (Isère at Montmélian, France)

Distance measured along a bridge

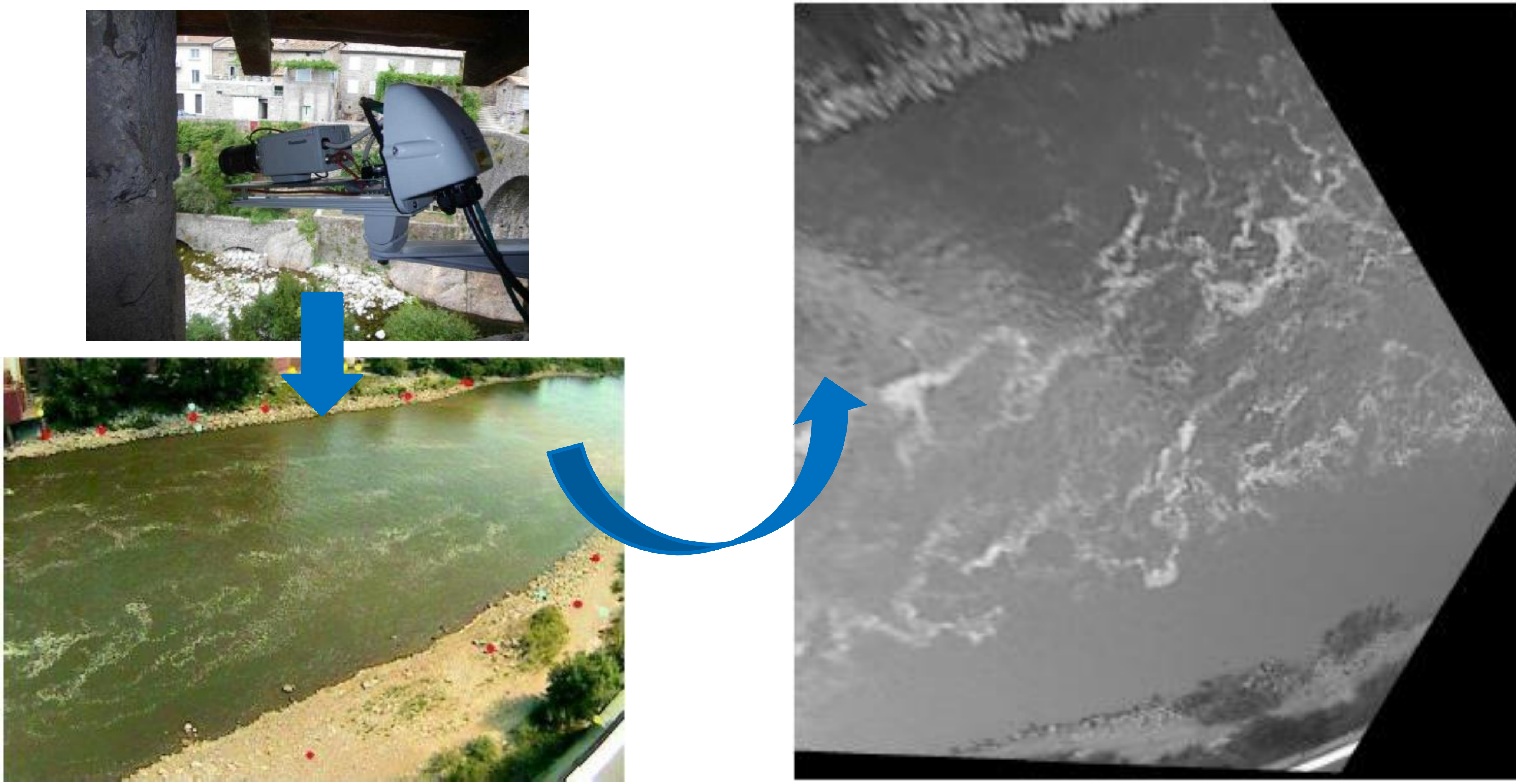
Object	Real size (m)	Image size (pixels)	Resolution (m/pix)
Between 2 piers	95	4667	0.020
Bridge width	11.25	592	0.019



Step 3. Velocity computation

Statistical analysis of flow tracers displacements

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



Step 3. Velocity computation

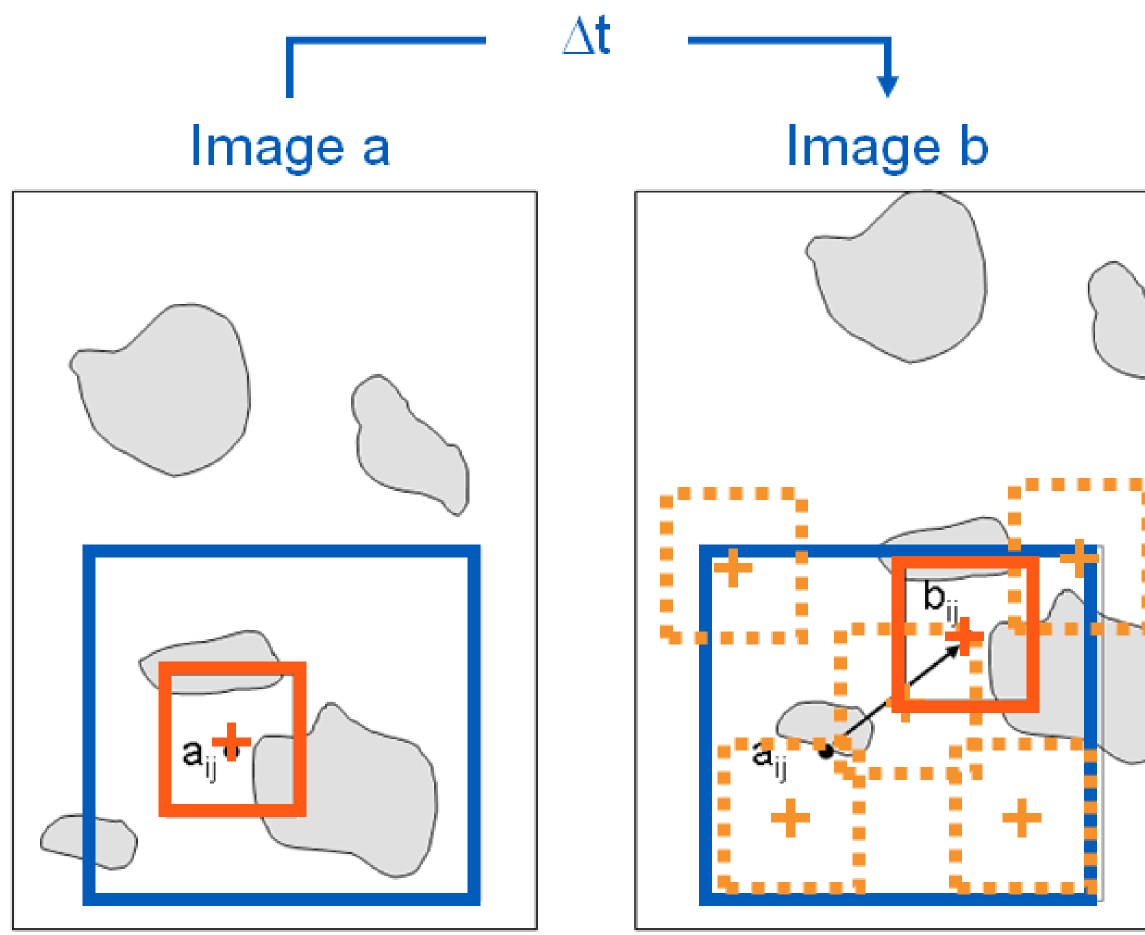
Statistical analysis of flow tracers displacements

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

Step 3. Velocity computation

LSPIV (Large Scale Particle Image Velocimetry, Fujita et al., 1998)

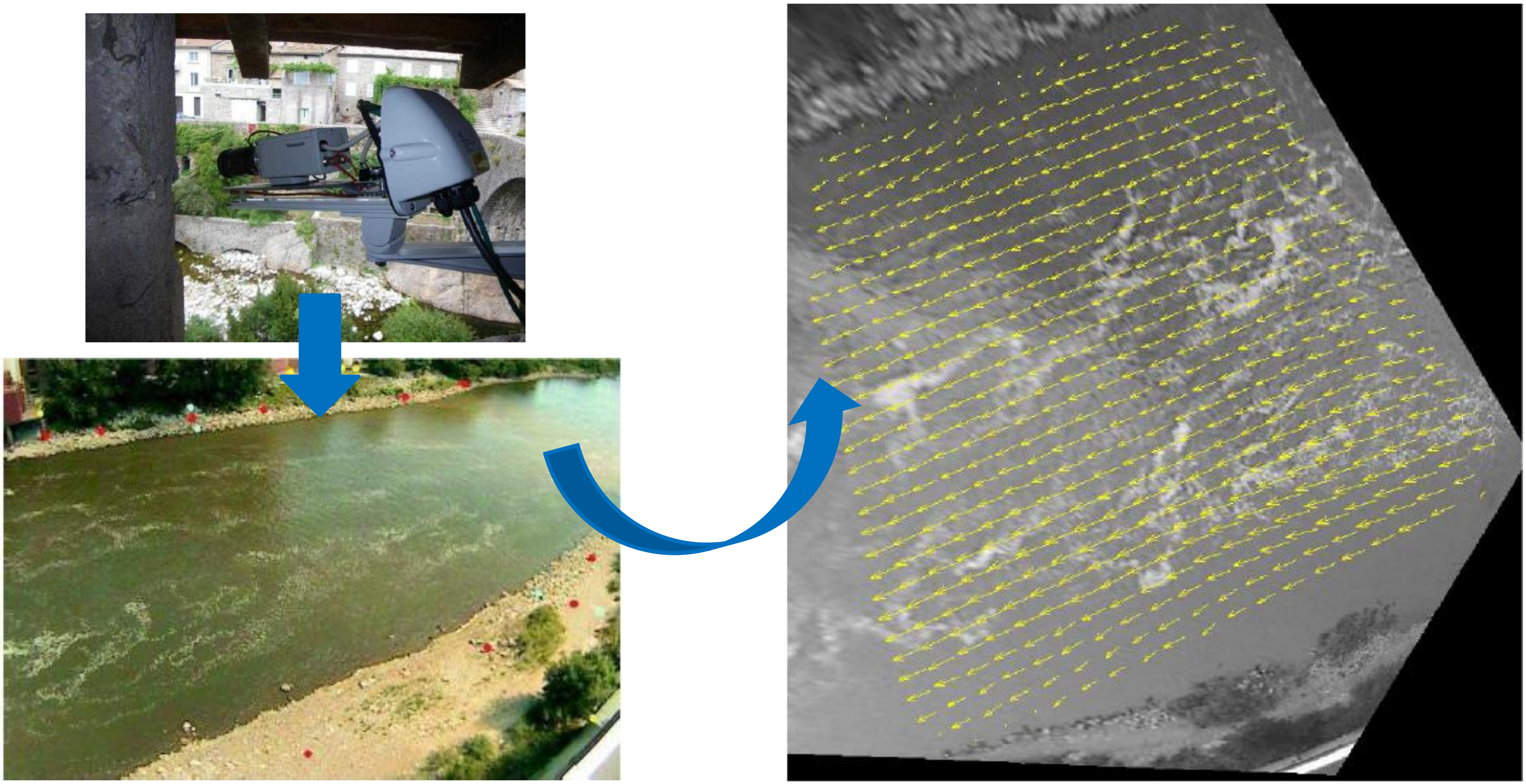
Detection of grayscale patterns motion through autocorrelation peaks



Step 3. Velocity computation

Statistical analysis of flow tracers displacements

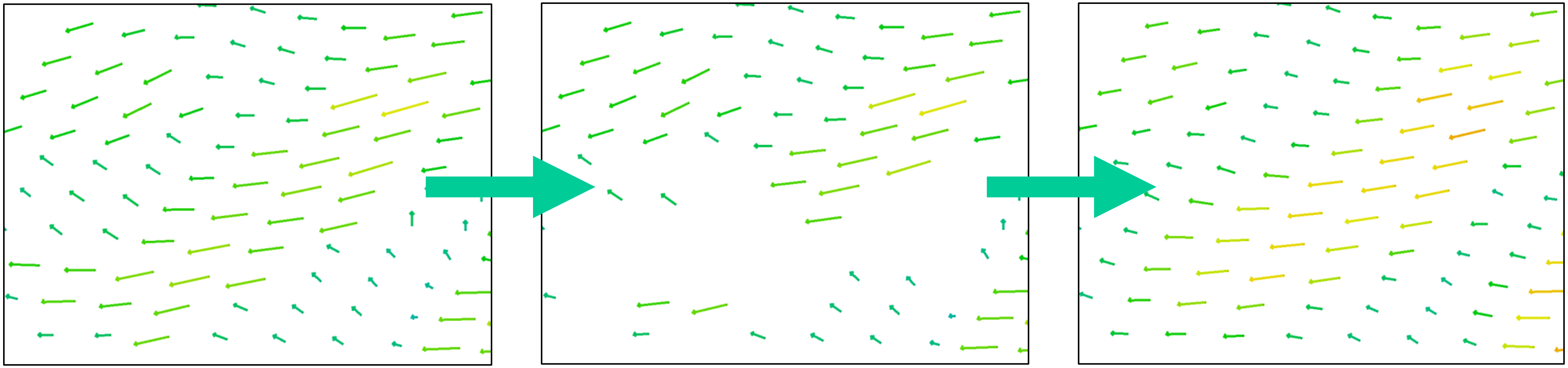
→ **computation of surface velocity vectors**



Velocity post-processing / filtering

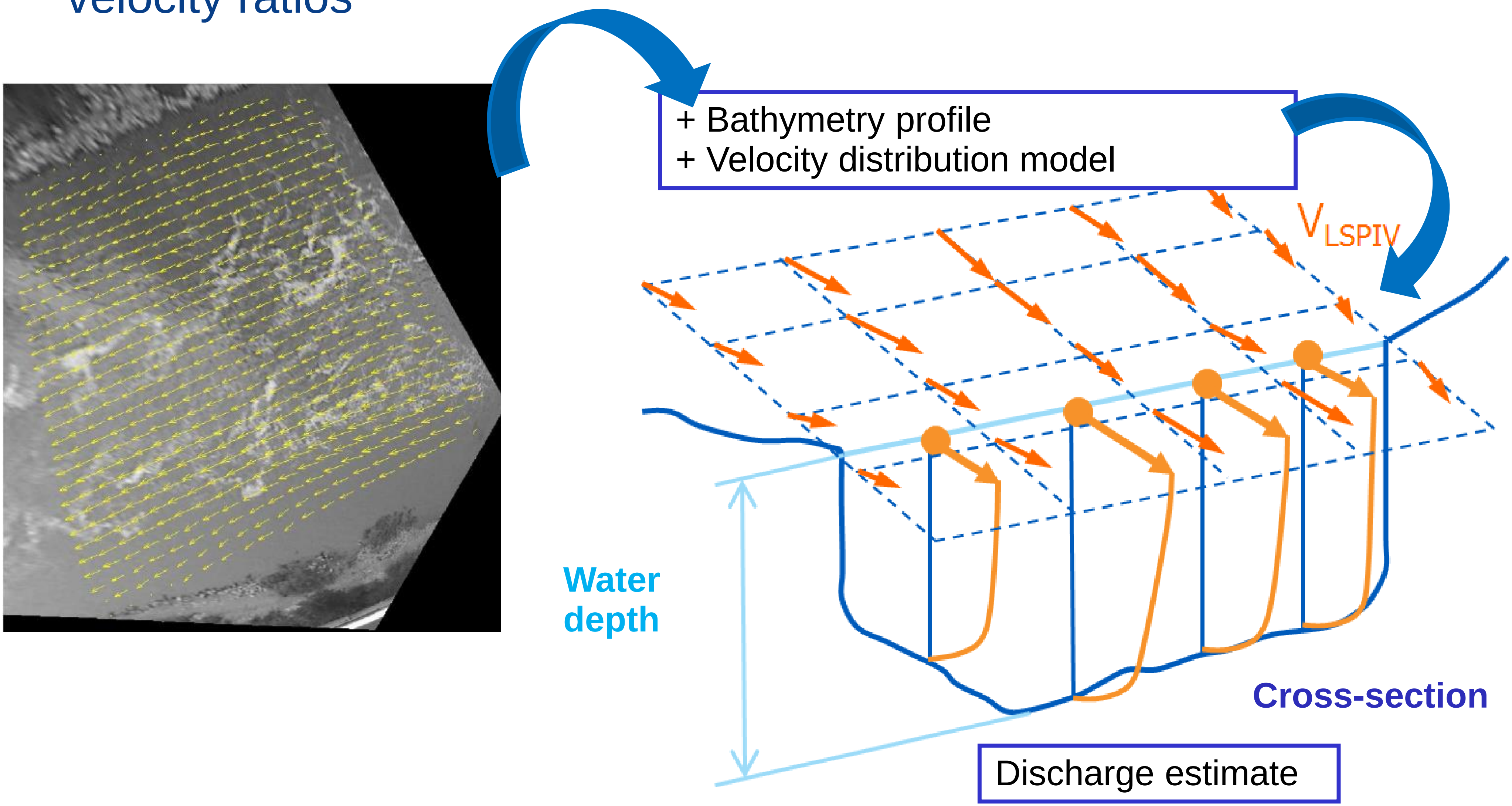
Very important step!

- ✓ **Screen out** spurious velocity results based on:
  - Correlation levels
  - Velocity magnitude and direction
  - Velocity coherence
  - etc.
- ✓ **Time-average** the surface velocity results
  - Long enough to average out statistical noise AND turbulence fluctuations
  - Short enough compared to streamflow variation



Step 4. Discharge computation

Estimation of discharge through a known cross-section
→ velocity-area method based on depth-average to surface velocity ratios



Surface velocity coefficient

α = depth-average velocity / surface velocity

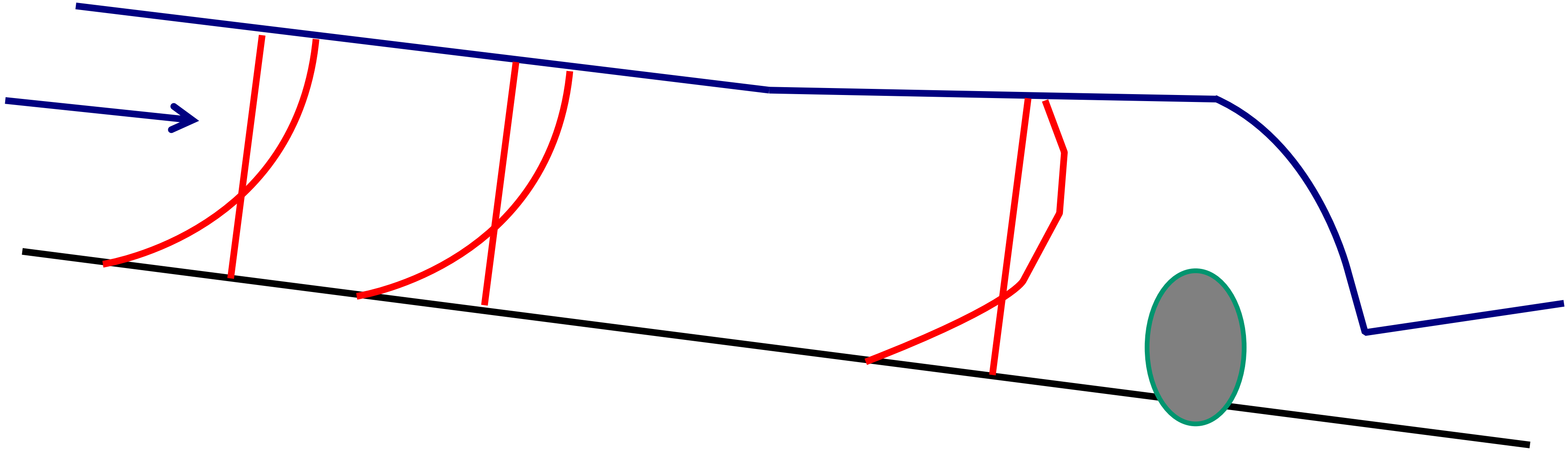
Rough estimate of α（ISO748）

	normal	smooth	rough	very rough	extreme cases
m	6~7	10	4	2~3	
α	0.86～0.87	0.91	0.80	0.67～0.75	0.60～1.2

Default value: α＝0.85

Surface velocity coefficient

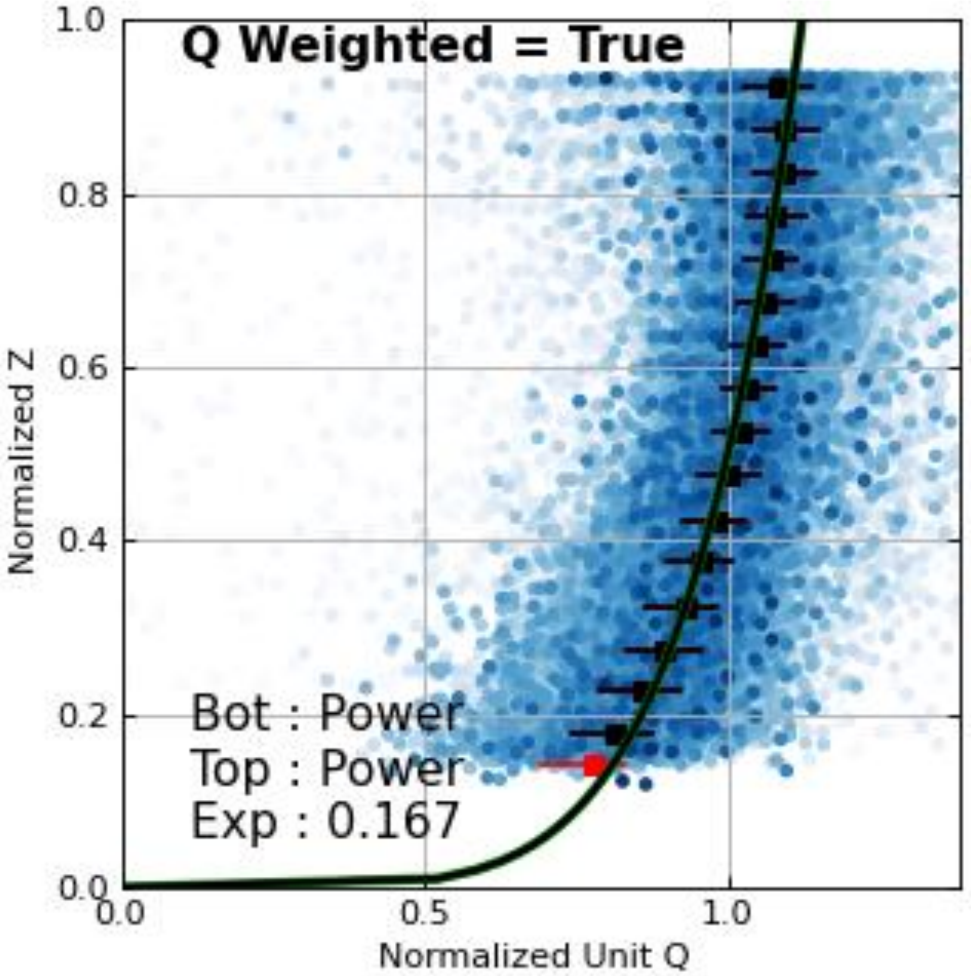
- The surface velocity coefficients
  - Can take different values in non uniform flow conditions
  - Typically:
    - Upstream of a weir or obstacles
    - In relatively narrow cross-sections



Surface velocity coefficient

- Can be calibrated from measured vertical velocity profiles

- ADCP commercial software or **QRevInt** provide the vertical velocity profile exponent 1/m



ADCP exponent	= 1/m	=	0.1667	0.25	0.10
Surface Vel Coeff	= m/(m+1)	=	0.86	0.80	0.91

Image velocimetry exercises

- ✓ Does everyone have Fudaa-LSPIV 1.9.2 running on their computer?
  - Double-click on fudaa-lspiv-xxx-setup.jar for installation
  - Possible issues due to Java version…

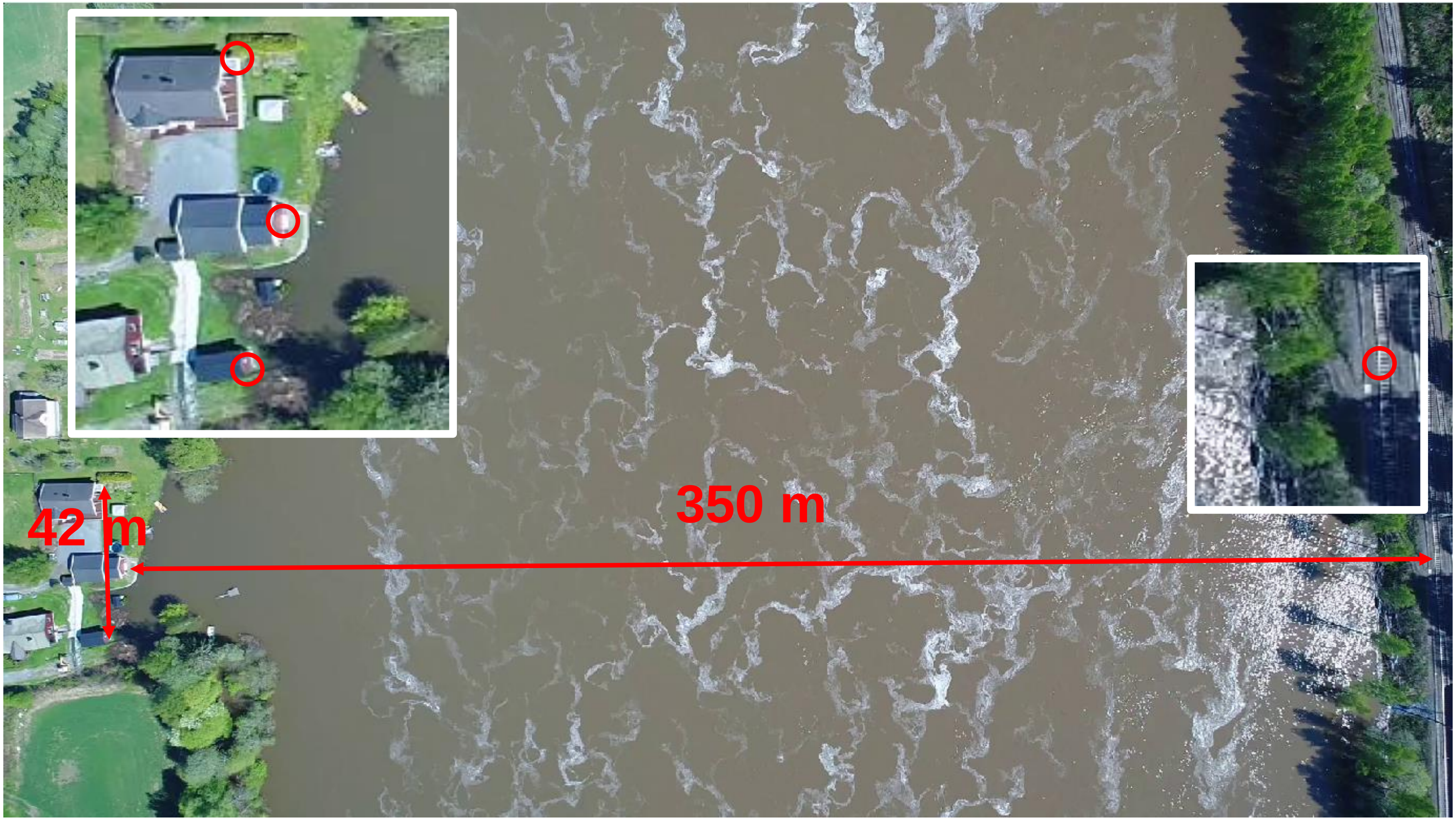
- ✓ Drone video over a large river:
  - Open file _TP_Drone.zip

- ✓ Flood chaser video:
  - Open file _TP_Cauterets.zip

All the necessary files are available here:
https://forge.irstea.fr/projects/fudaa-lspiv/files

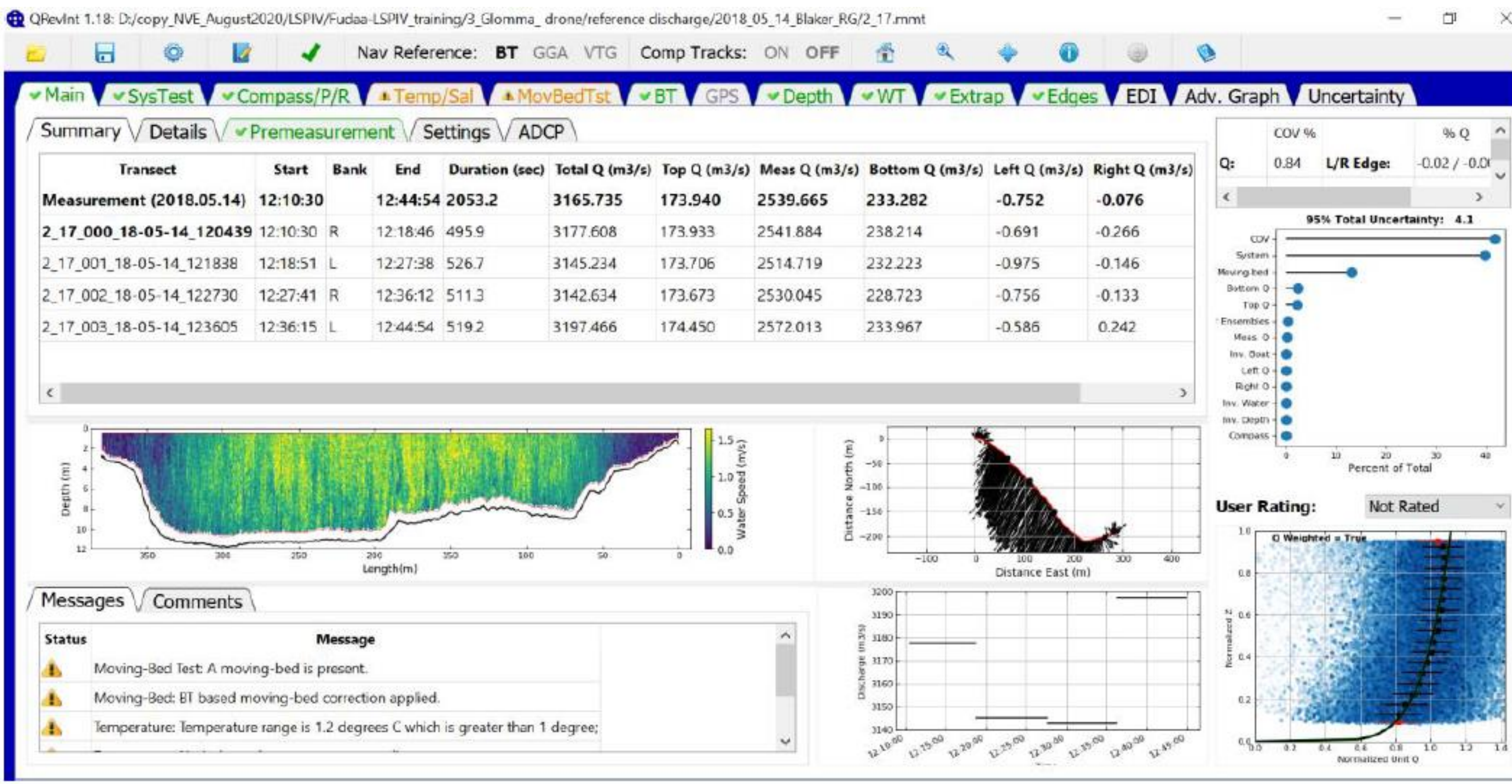
Drone video

- Large flood in Scandinavia
- Vertical viewpoint, stable, 150 m high
- Natural tracers (foam)
- Orthorectification by scaling: 2 distances
- ADCP gauging: 3165 m^3/s



Drone video

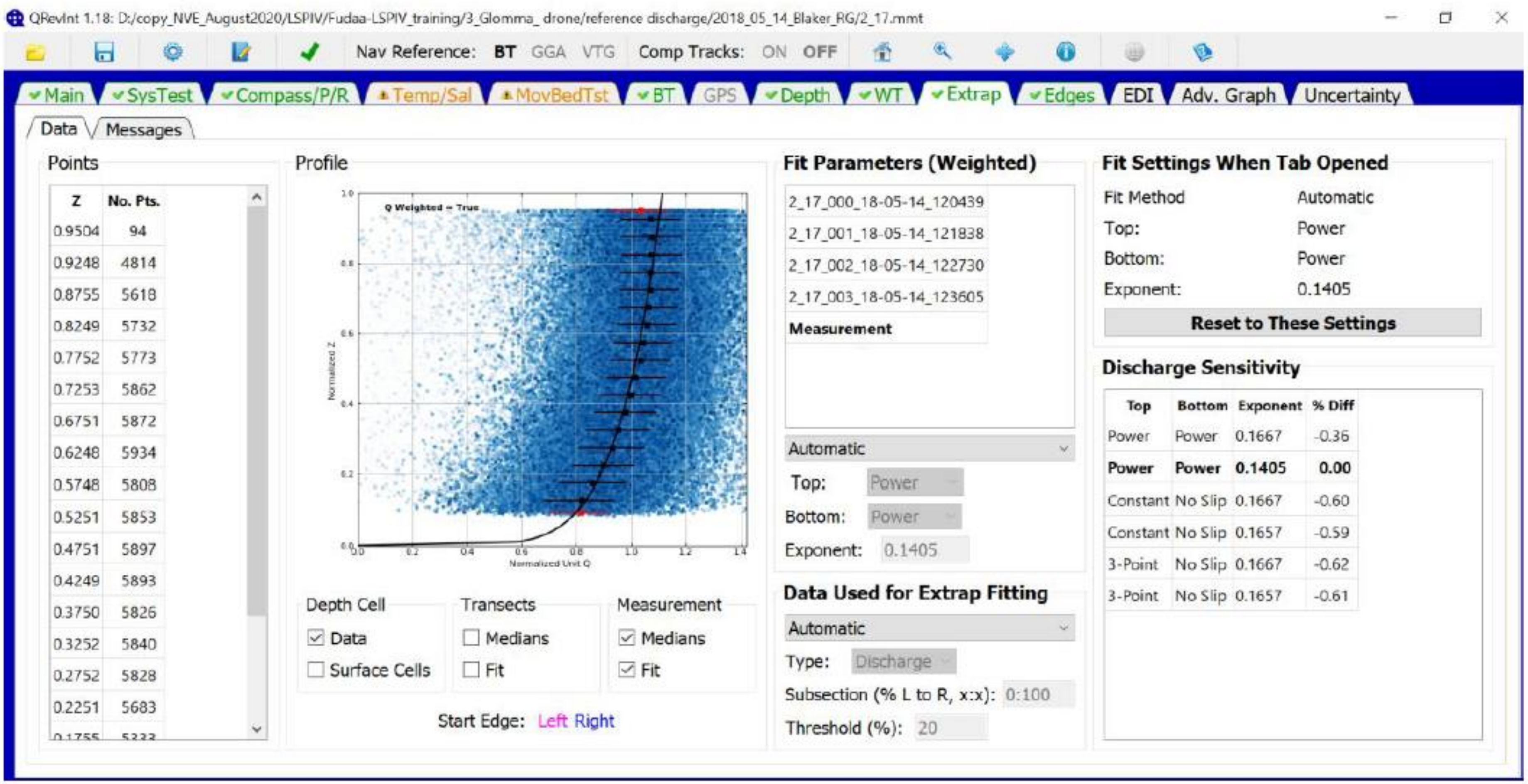
- Large flood in Scandinavia
- Vertical viewpoint, stable, 150 m high
- Natural tracers (foam)
- Orthorectification by scaling: 2 distances
- ADCP gauging: 3166 m^3/s; **cross-sectional bathymetry**



Transect	Start	Bank	End	Duration (sec)	Total Q (m3/s)	Top Q (m3/s)	Meas Q (m3/s)	Bottom Q (m3/s)	Left Q (m3/s)	Right Q (m3/s)
Measurement (2018.05.14)	**12:10:30**		**12:44:54**	**2053.2**	**3165.735**	**173.940**	**2539.665**	**233.282**	**-0.752**	**-0.076**
2_17_000_18-05-14_120439	12:10:30	R	12:18:46	495.9	3177.608	173.933	2541.884	238.214	-0.691	-0.266
2_17_001_18-05-14_121838	12:18:51	L	12:27:38	526.7	3145.234	173.706	2514.719	232.223	-0.975	-0.146
2_17_002_18-05-14_122730	12:27:41	R	12:36:12	511.3	3142.634	173.673	2530.045	228.723	-0.756	-0.133
2_17_003_18-05-14_123605	12:36:15	L	12:44:54	519.2	3197.466	174.450	2572.013	233.967	-0.586	0.242

Drone video

- Large flood in Scandinavia
- Vertical viewpoint, stable, 150 m high
- Natural tracers (foam)
- Orthorectification by scaling: 2 distances
- ADCP gauging: 3166 m^3/s; **exponent 1/m = 0.1405**



Flood chaser video

- Gave de Cauterets River at Cauterets hydrometric station
- Historic flood of June 2013 in the Pyrenees, France

Flood chaser video

- Video collected on YouTube after the destruction of the hydrometric station by the flood
- 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

Flood chaser video

- Gave de Cauterets River at Cauterets hydrometric station
- Historic flood of June 2013 in the Pyrenees, France
- Survey of 2 distances for orthorectification
- Natural tracers (turbulence patterns)
- GoPro camera: images corrected (wide angle) and aligned