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

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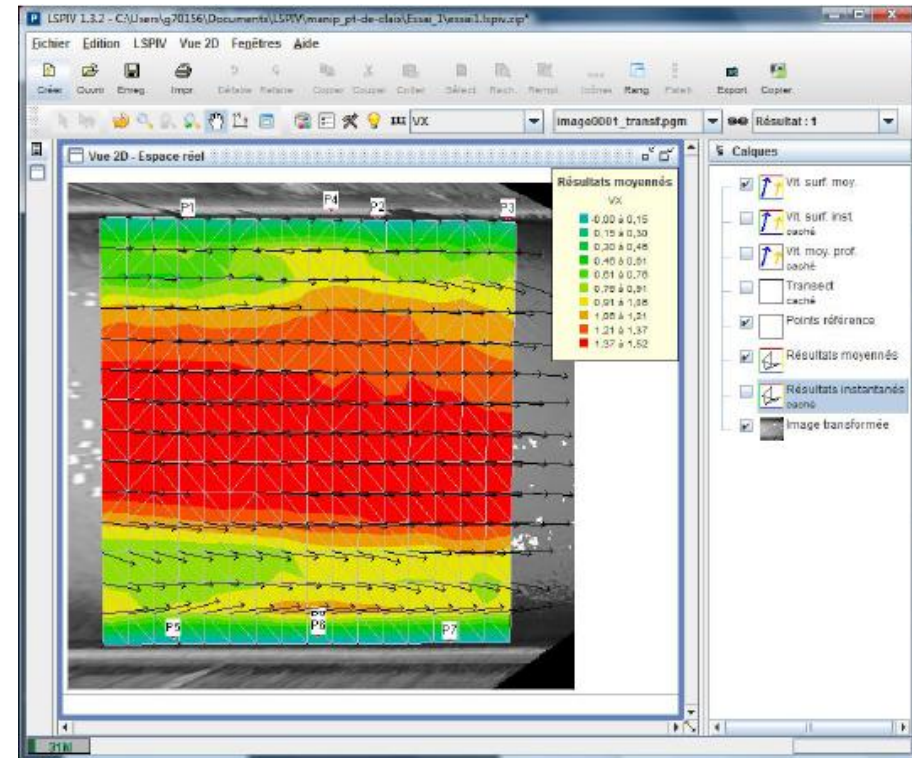




Image-based velocity and discharge measurements using the free FUDAA-LSPIV software

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)



$$i = \frac{a_1 X + a_2 Y + a_3 Z + a_4}{a_9 X + a_{10} Y + a_{11} Z + 1}$$
$$j = \frac{a_5 X + a_6 Y + a_7 Z + a_8}{a_9 X + a_{10} Y + a_{11} Z + 1}$$

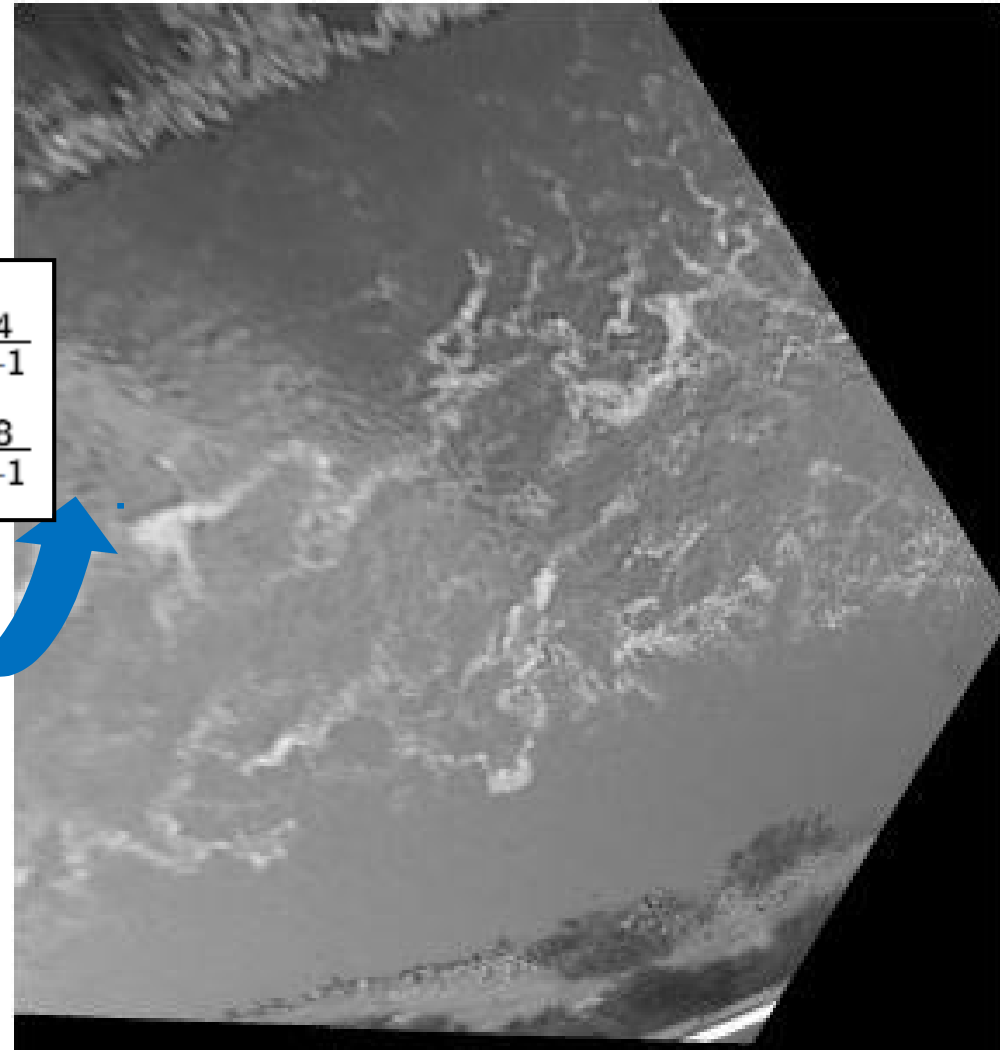


Principles of the LSPIV technique

Step 3. Orthorectification of gray-scale images



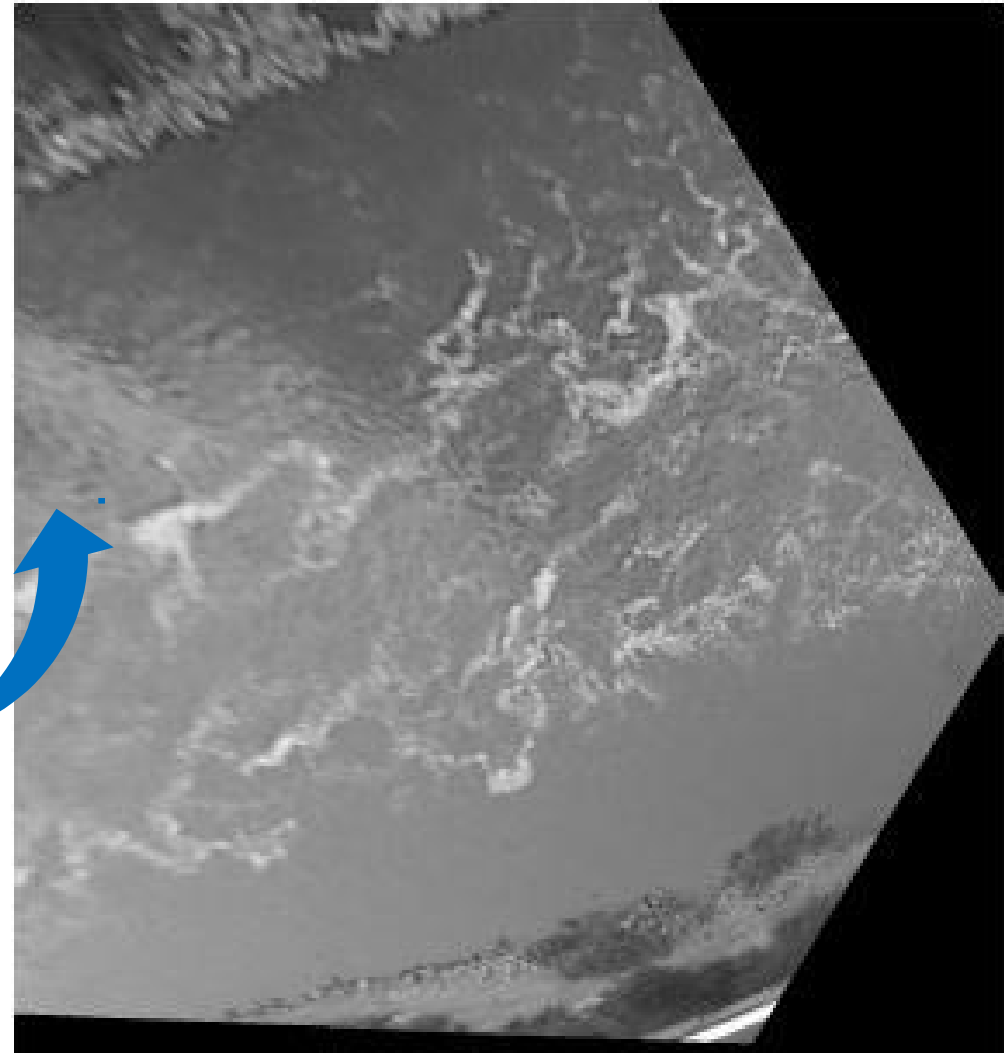
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Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

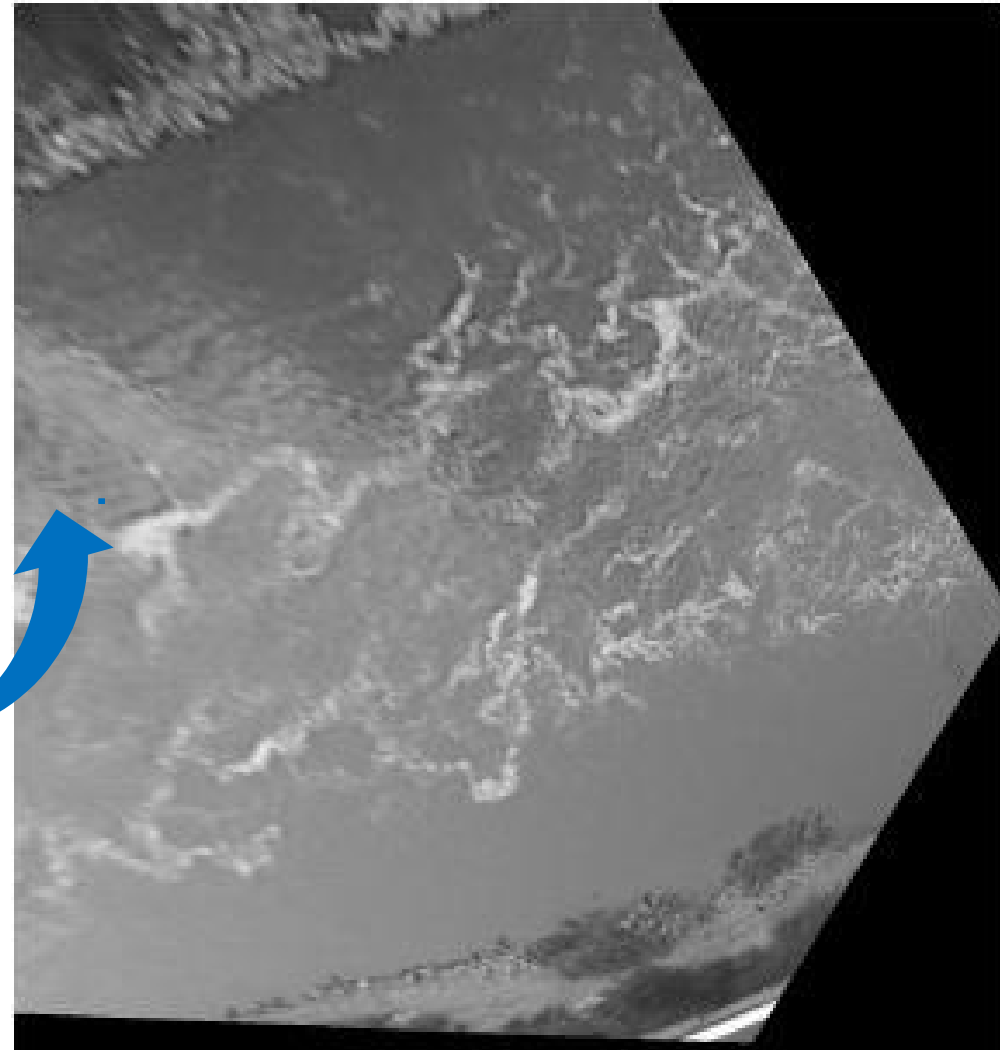
→ artificial seeding or natural tracers (floating objects, turbulence patterns, etc.)



Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

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

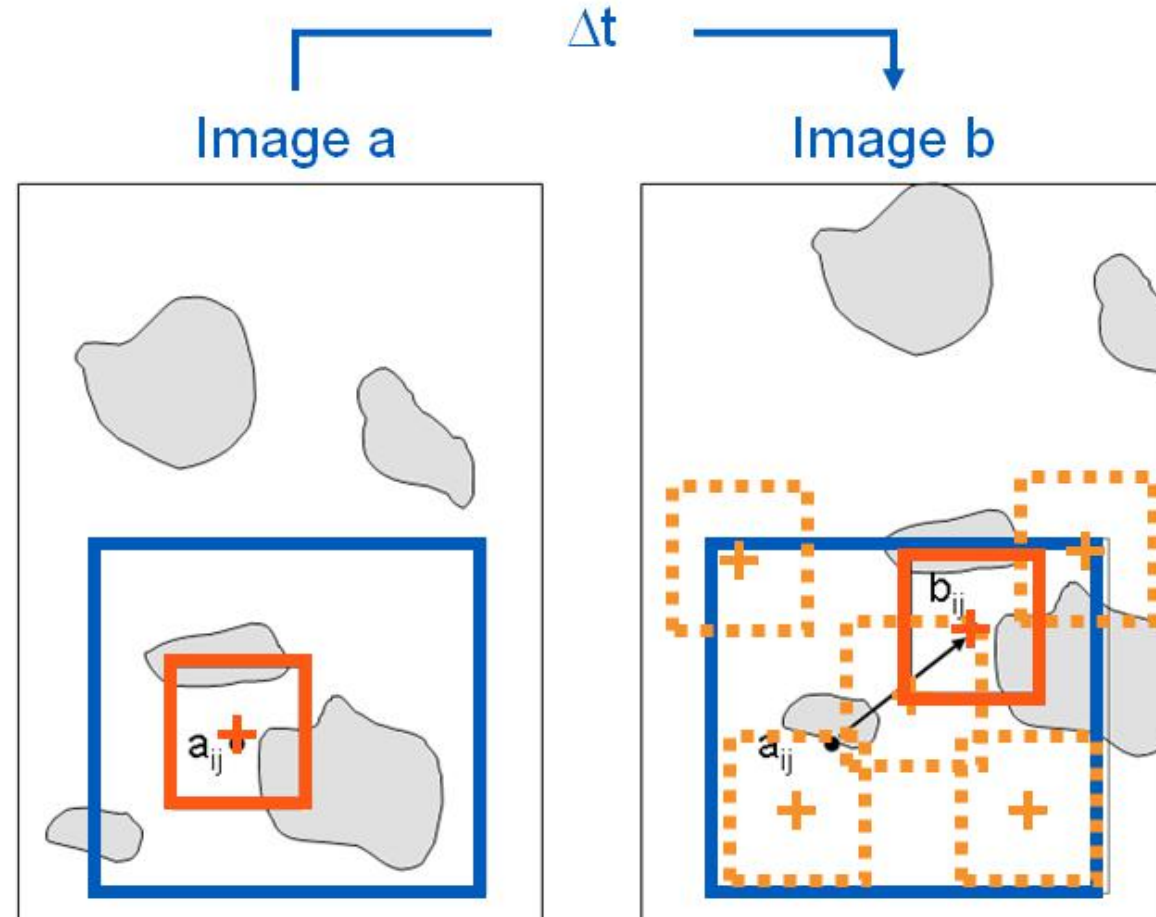


Principles of the LSPIV technique

Step 4. Statistical analysis of flow tracers displacements

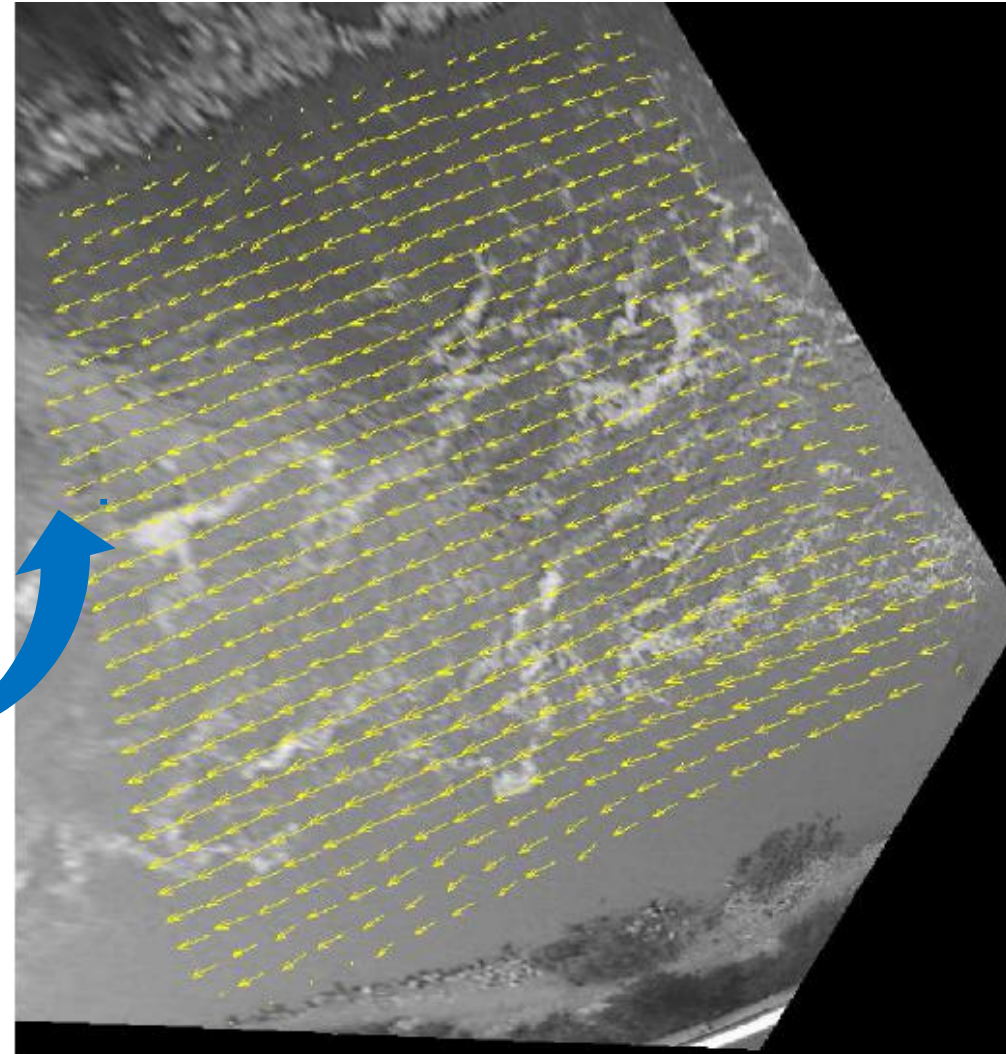
→ based on cross-correlation analysis

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



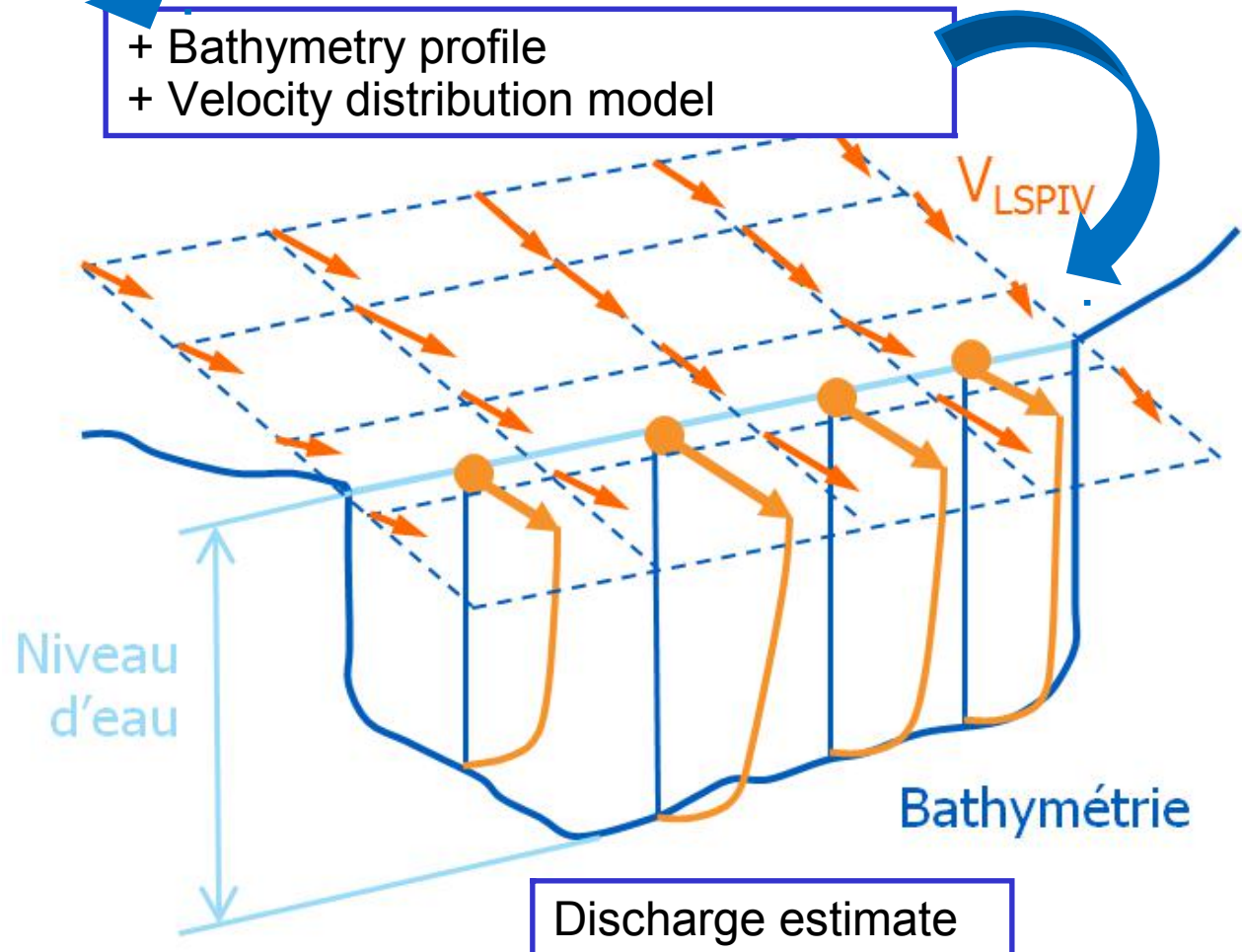
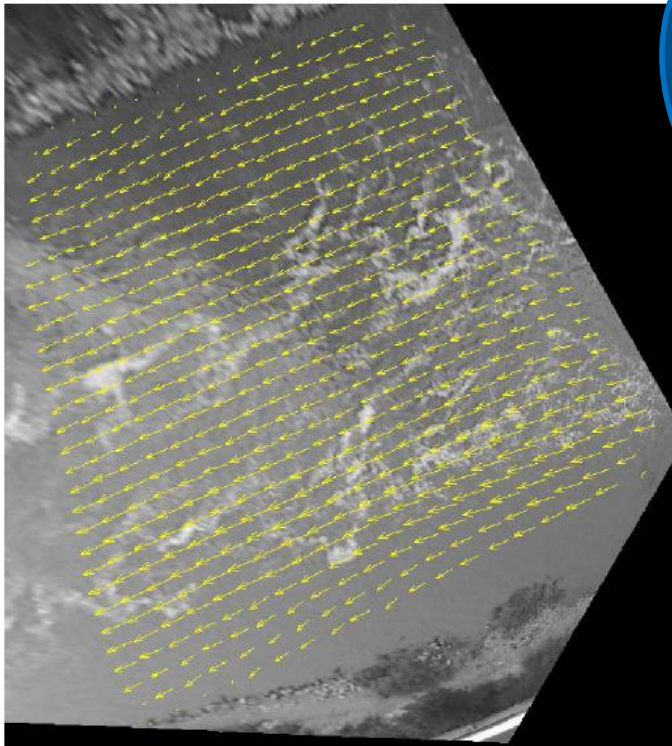
Principles of the LSPIV technique

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-averaged to surface velocity ratio



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)

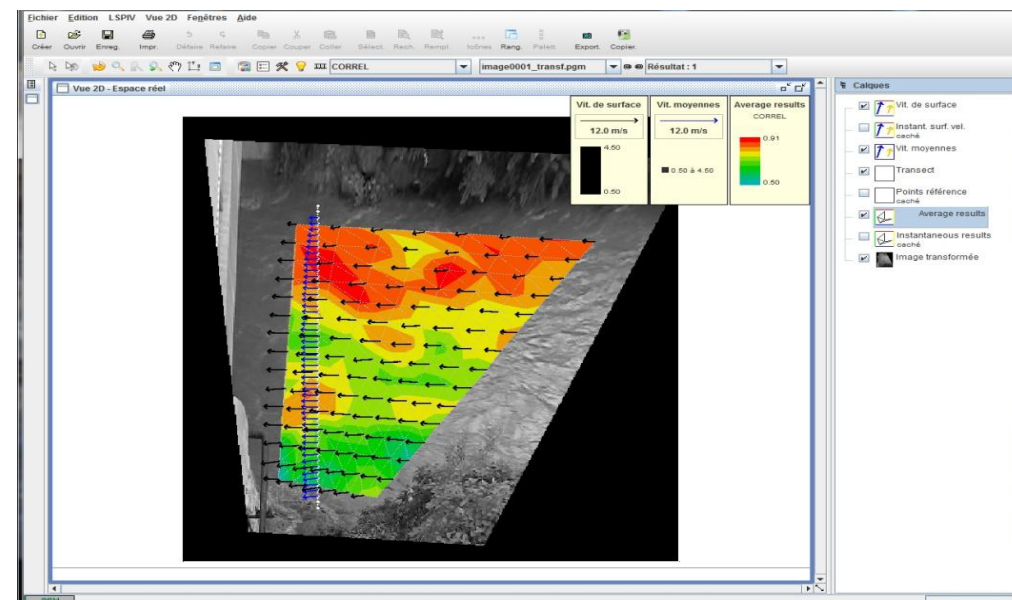
Sharing the method and software

- 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)



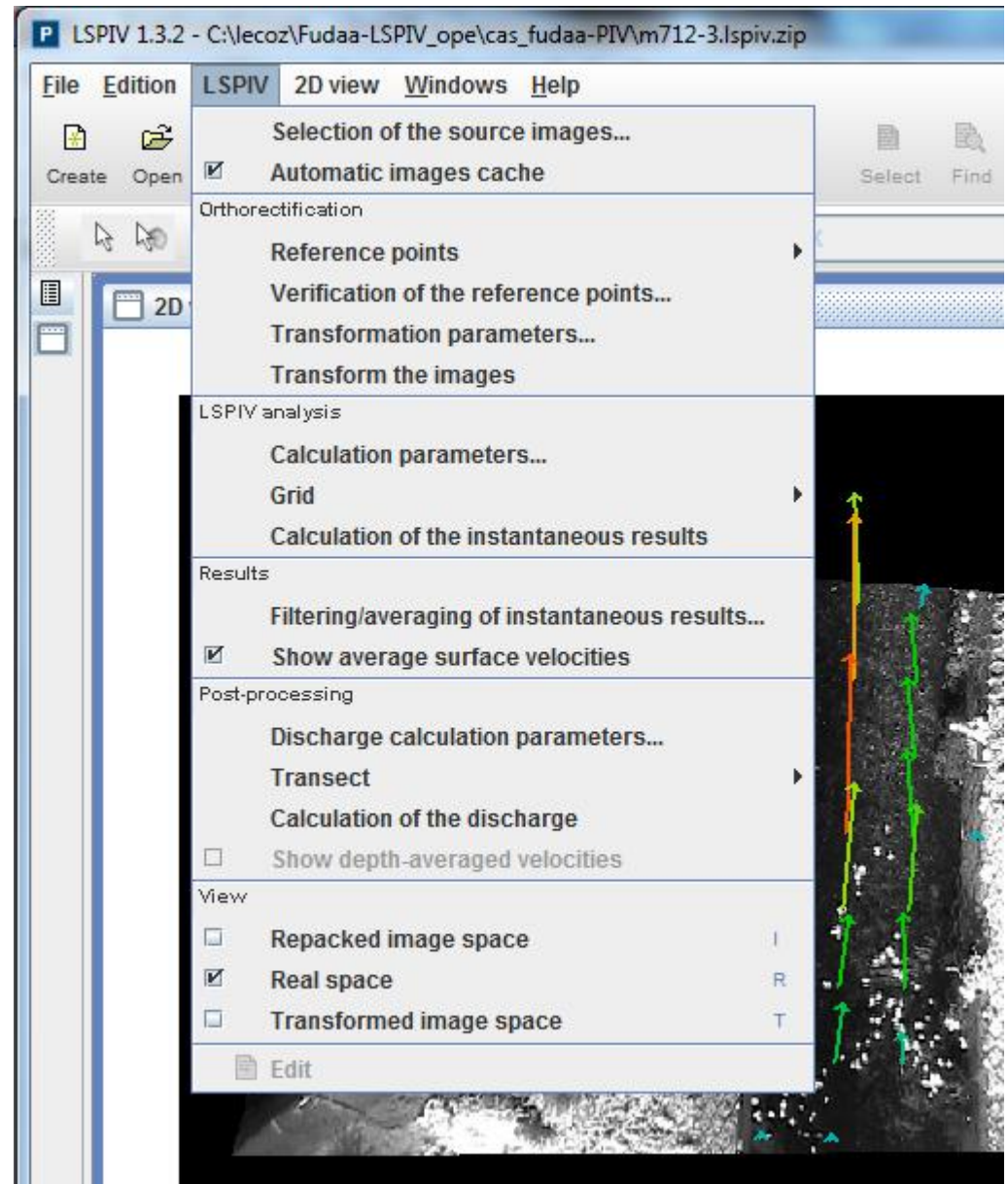
Fudaa-LSPIV software: Structure and functions

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:

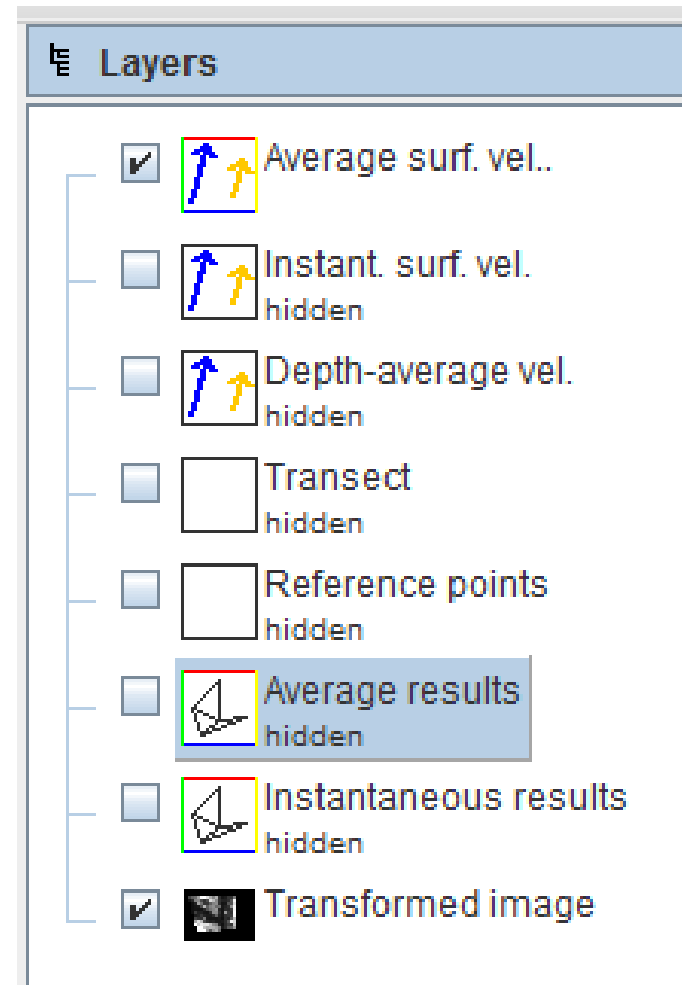
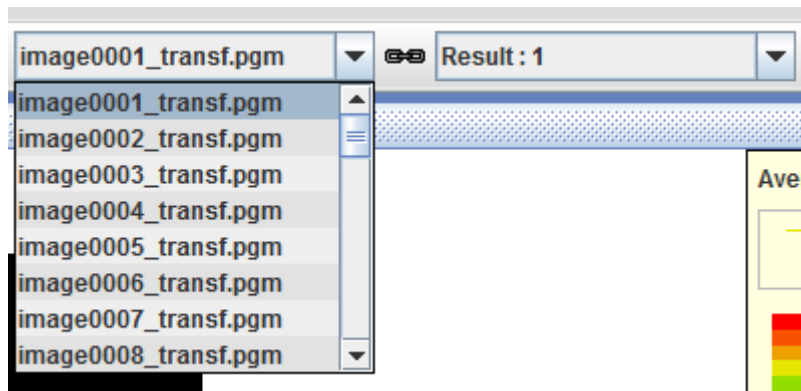
- Source images
- Orthorectification
- PIV analysis
- Results processing
- Discharge computation



Fudaa-LSPIV software: Structure and functions

Visualization and exportations:

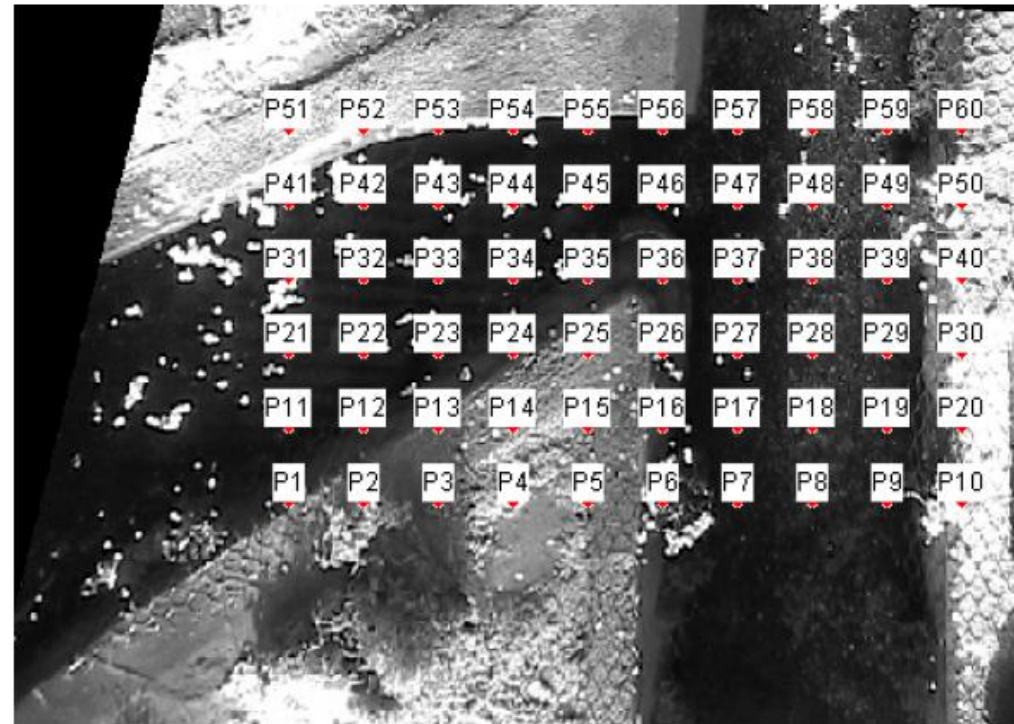
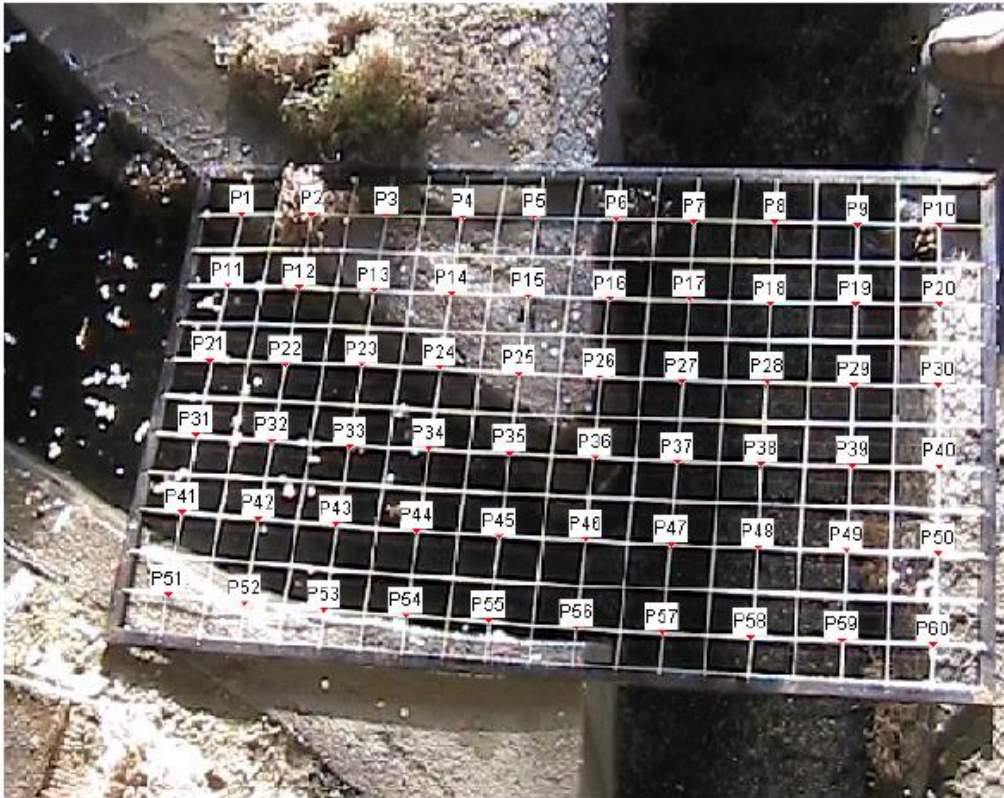
- layers, variables
- editable captions
- animation, data and picture outputs



Laboratory: recirculation flow in a meander outlet

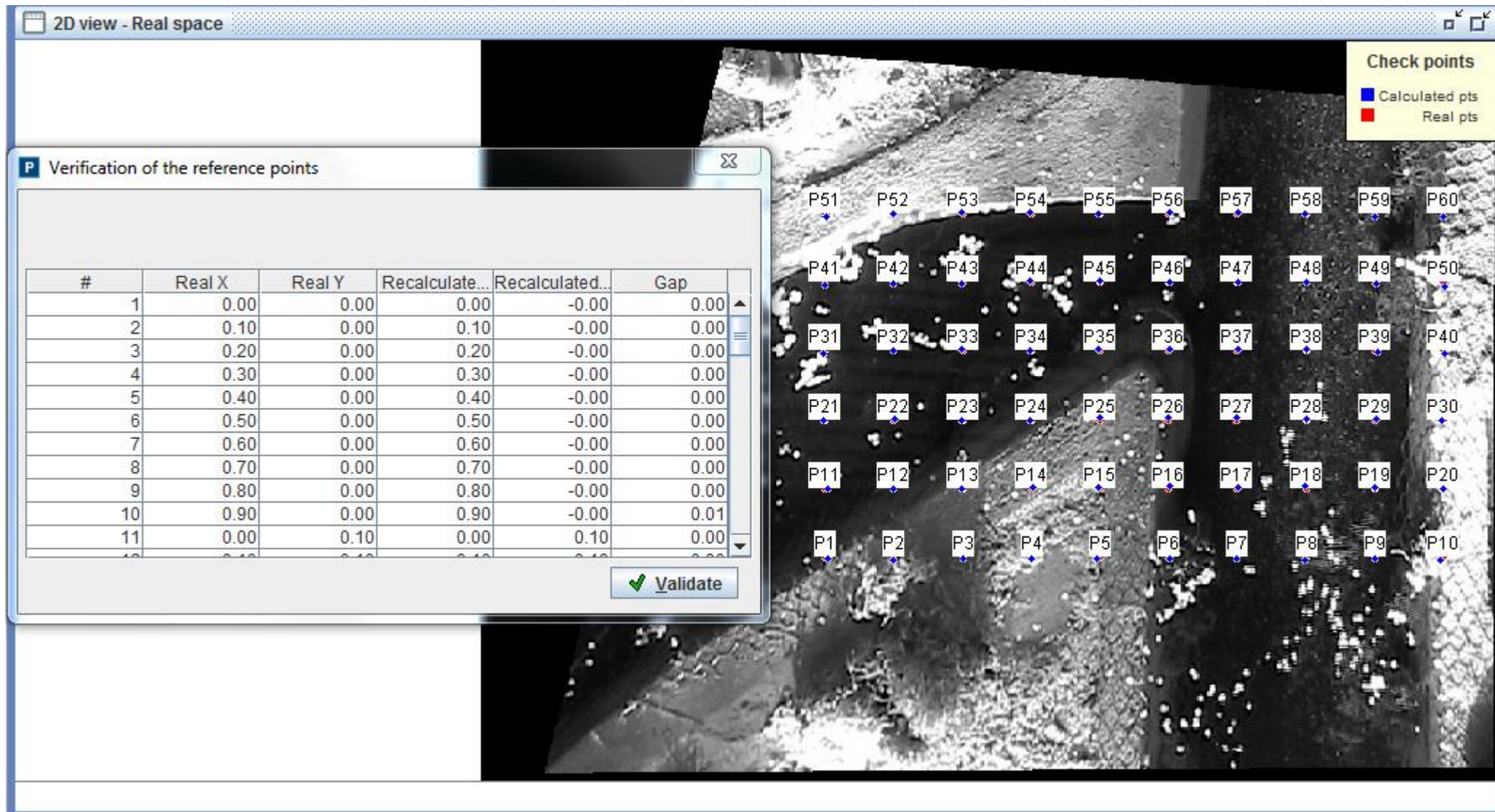
Physical model of the Morava River to design the reconnection of cut-off meanders (VUVH, Bratislava, Slovakia, cf. [Le Coz et al., ESPL, 2010](#))

Defining GRPs...



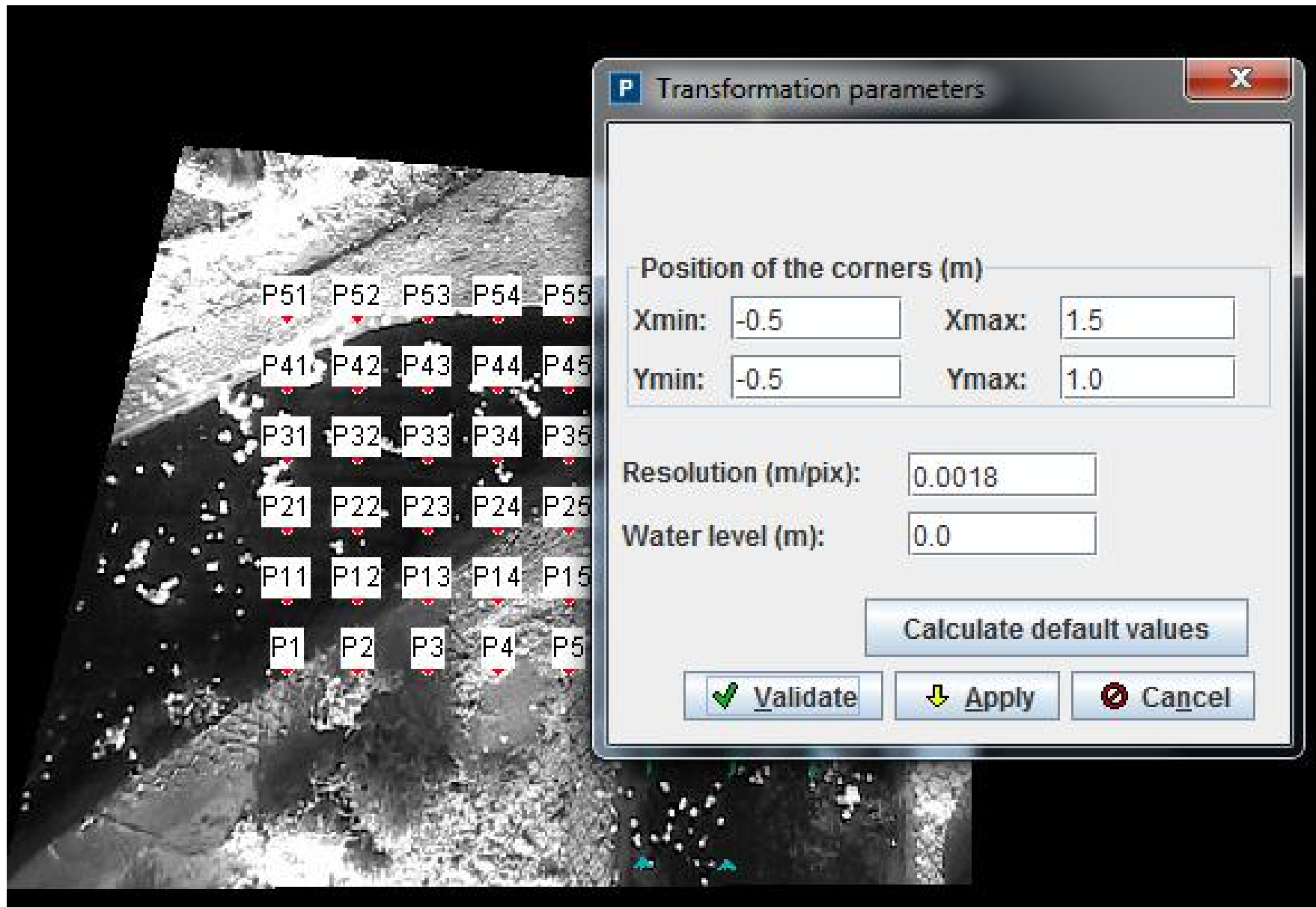
Laboratory: recirculation flow in a meander outlet

Verification of the accuracy of the orthorectification matrix:
Comparison of the real and computed positions of GRPs



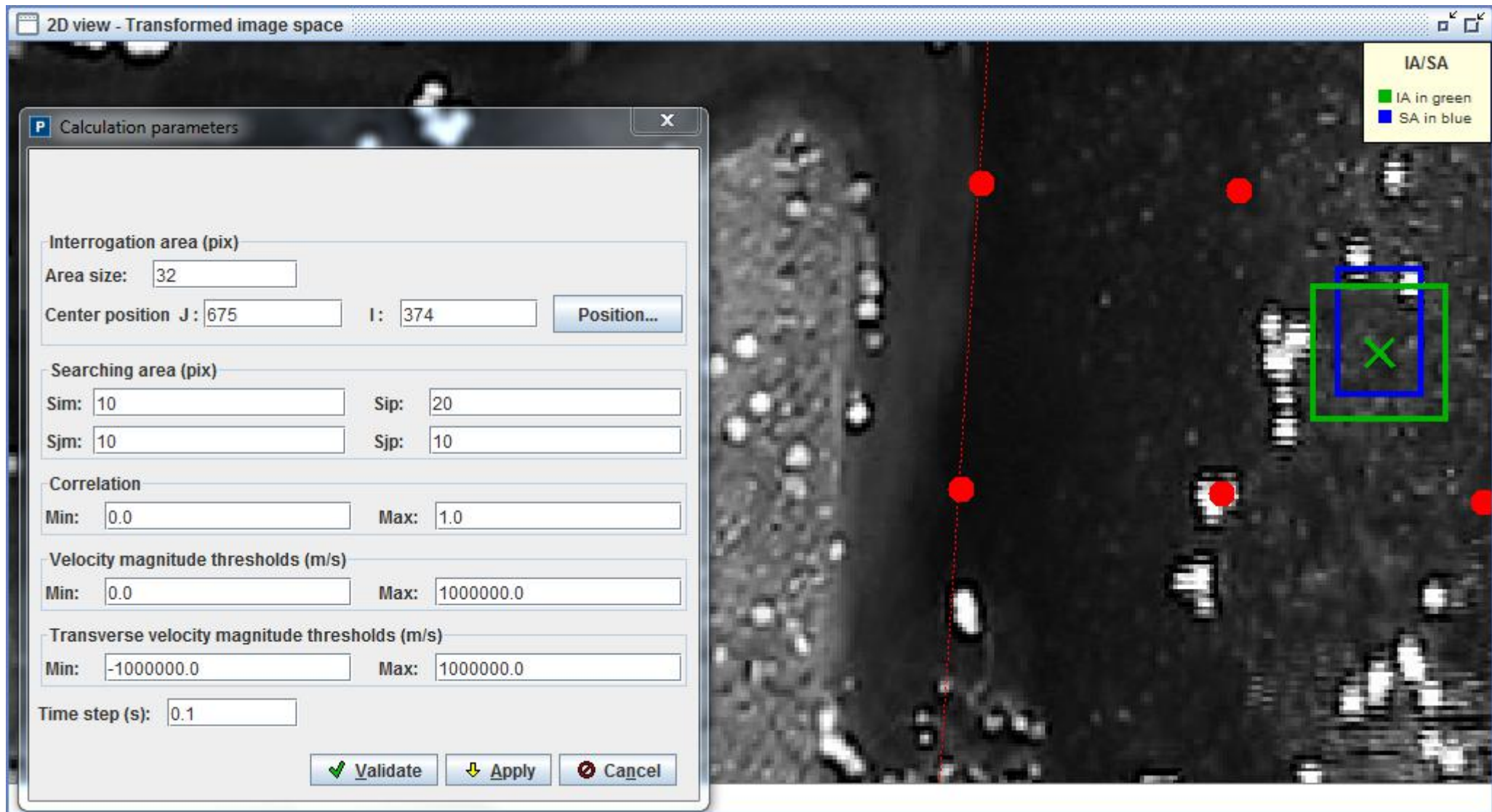
Laboratory: recirculation flow in a meander outlet

Definition of image transformation parameters



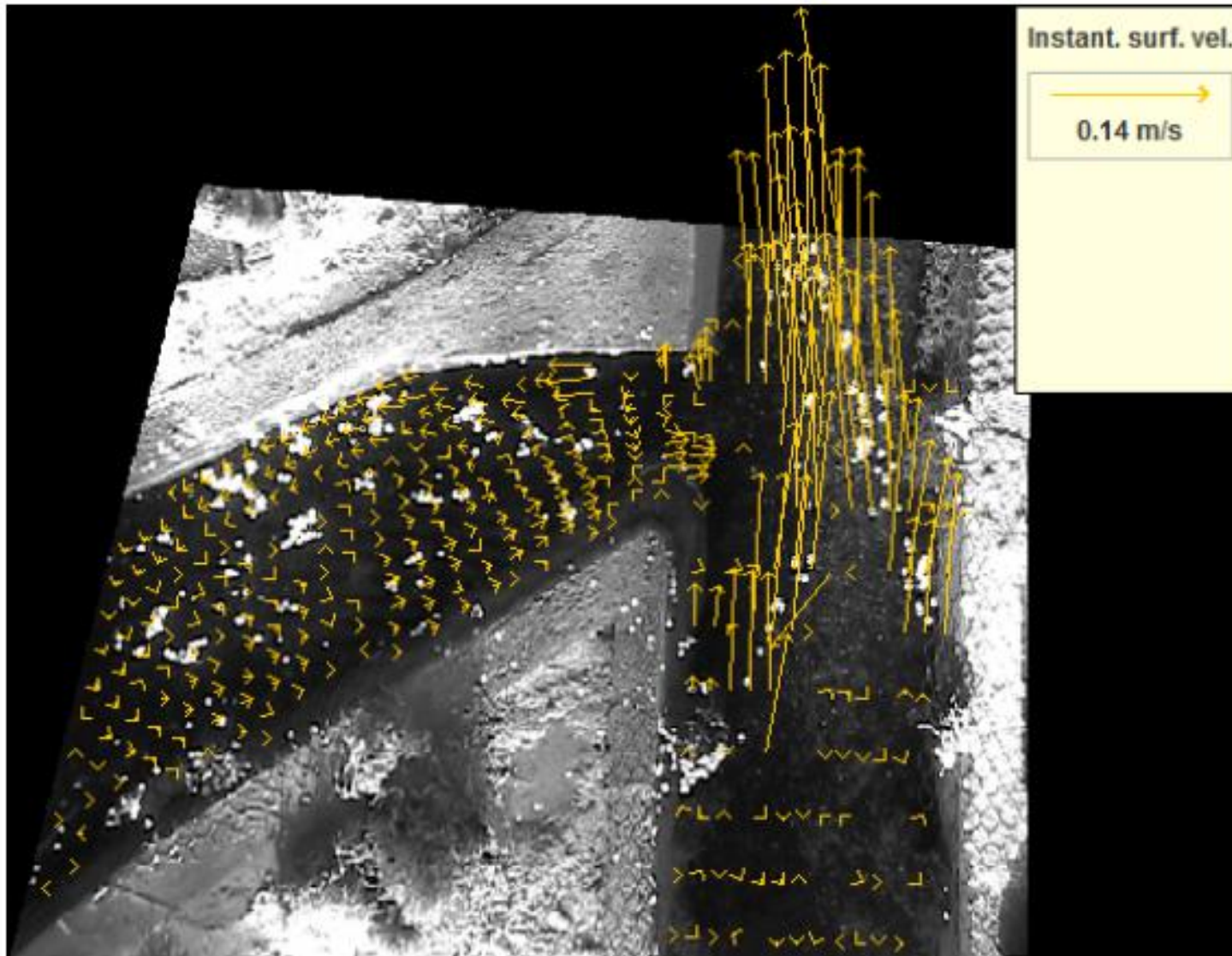
Laboratory: recirculation flow in a meander outlet

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



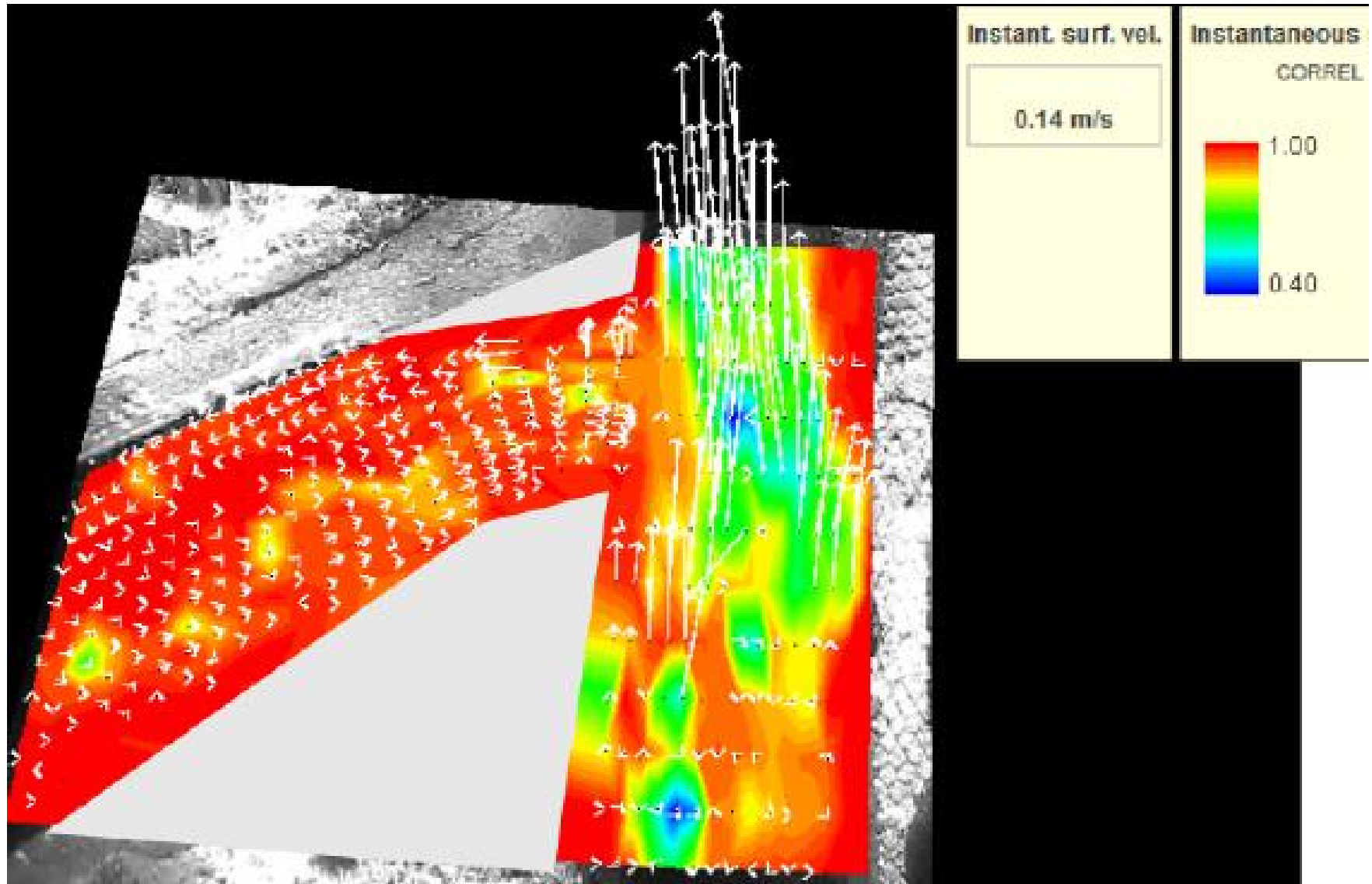
Laboratory: recirculation flow in a meander outlet

Instantaneous velocity field (1 image pair)



Laboratory: recirculation flow in a meander outlet

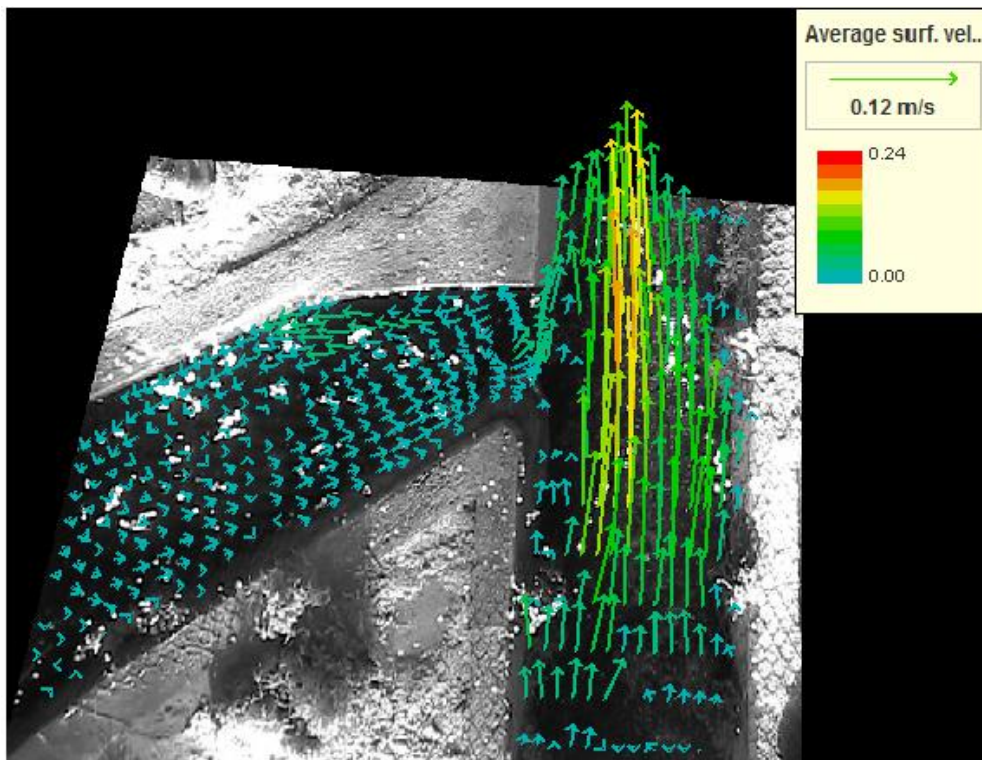
Instantaneous velocity field + correlation contours



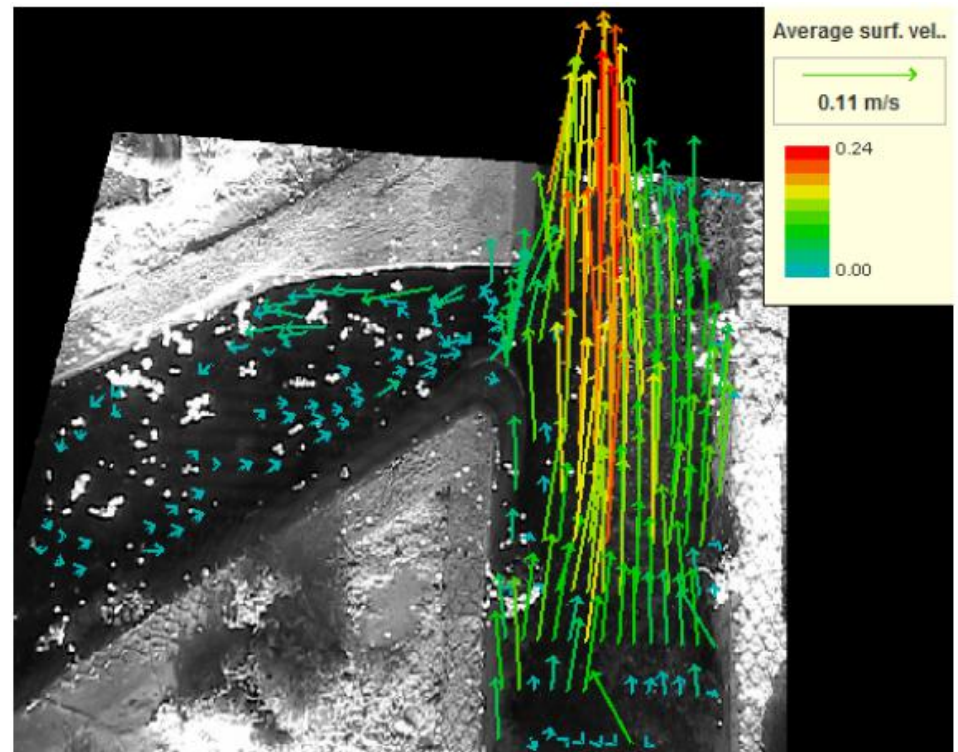
Laboratory: recirculation flow in a meander outlet

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

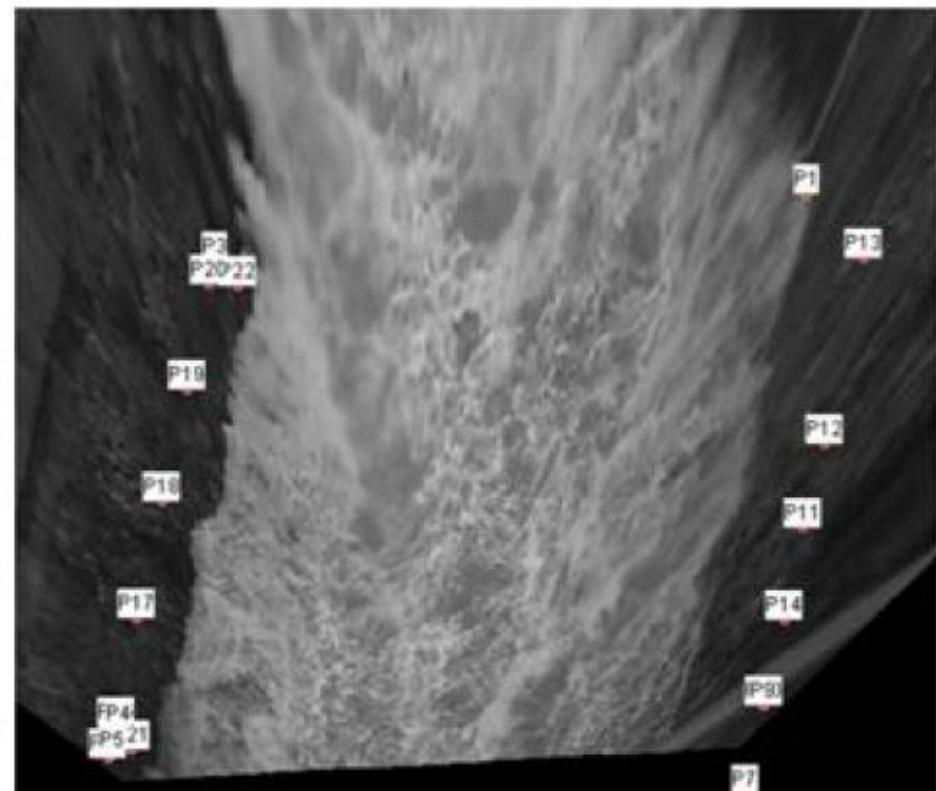
Achieve field topography survey : GRPs, bathymetry profiles,
water level estimation

Then go with Fudaa-LSPIV...



Field: flood streamgauging from YouTube home movies

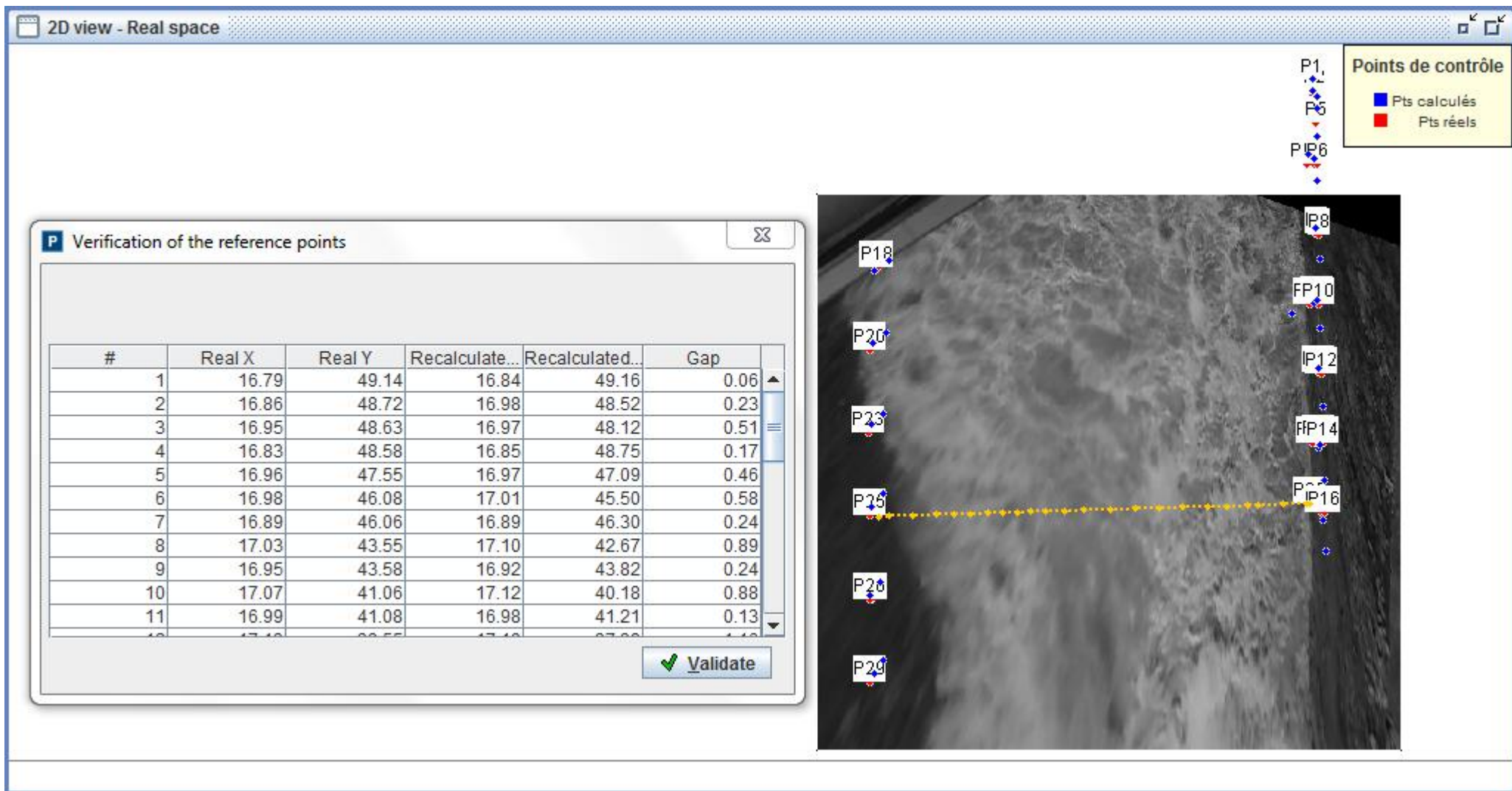
GRP positioning and image orthorectification



Field: flood streamgauging from YouTube home movies

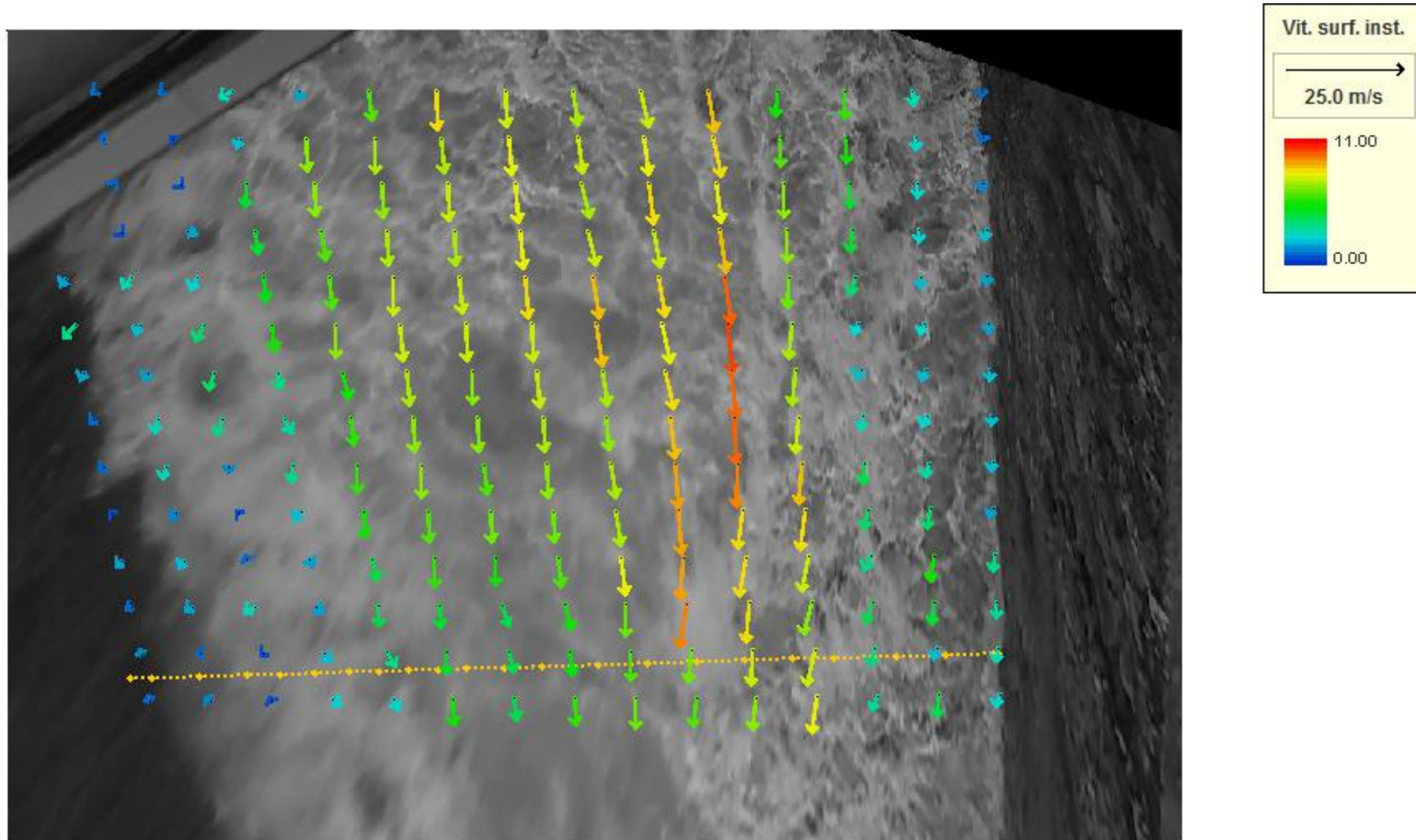
Verification of the accuracy of the orthorectification matrix:

Comparison of the real and computed positions of GRPs



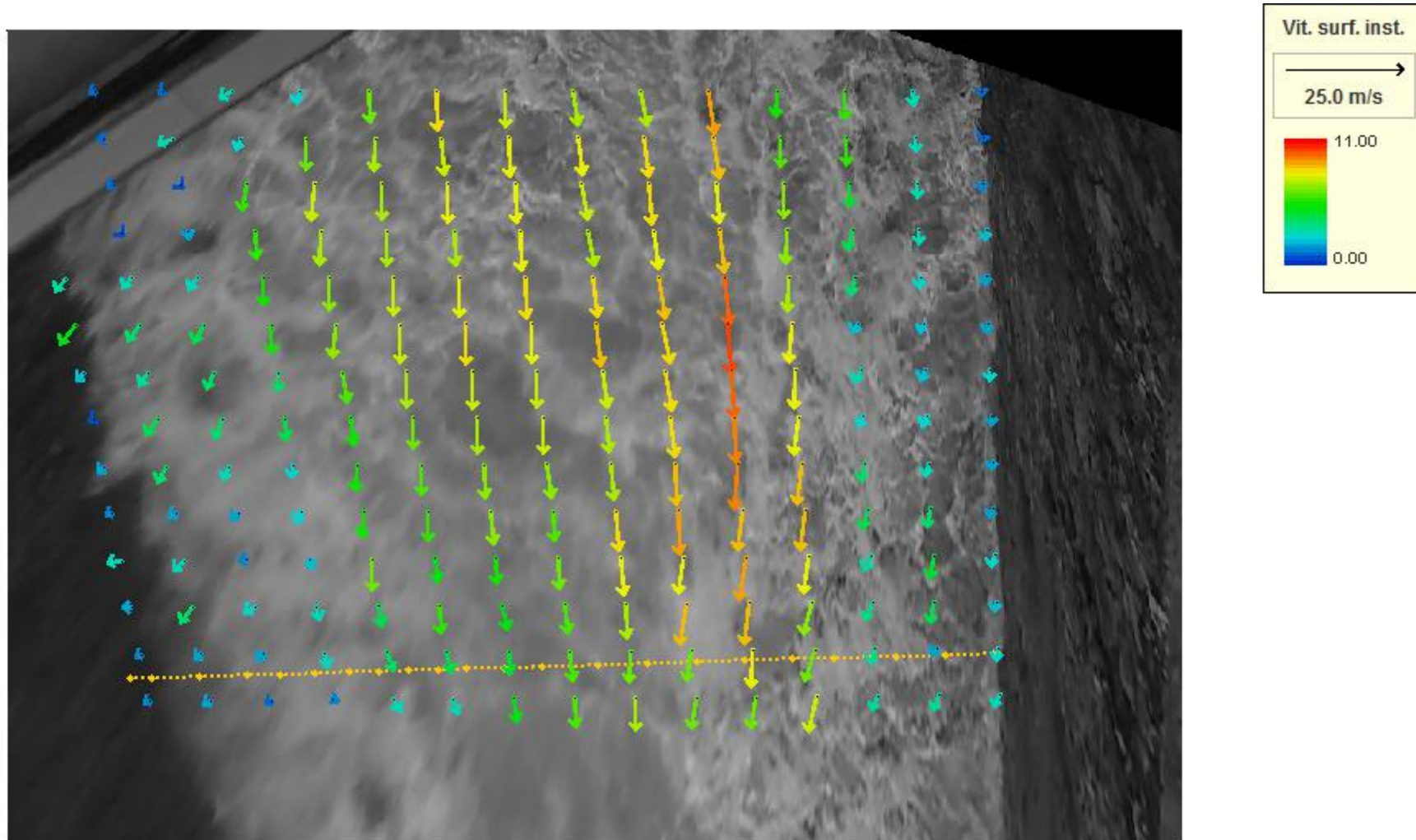
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #1



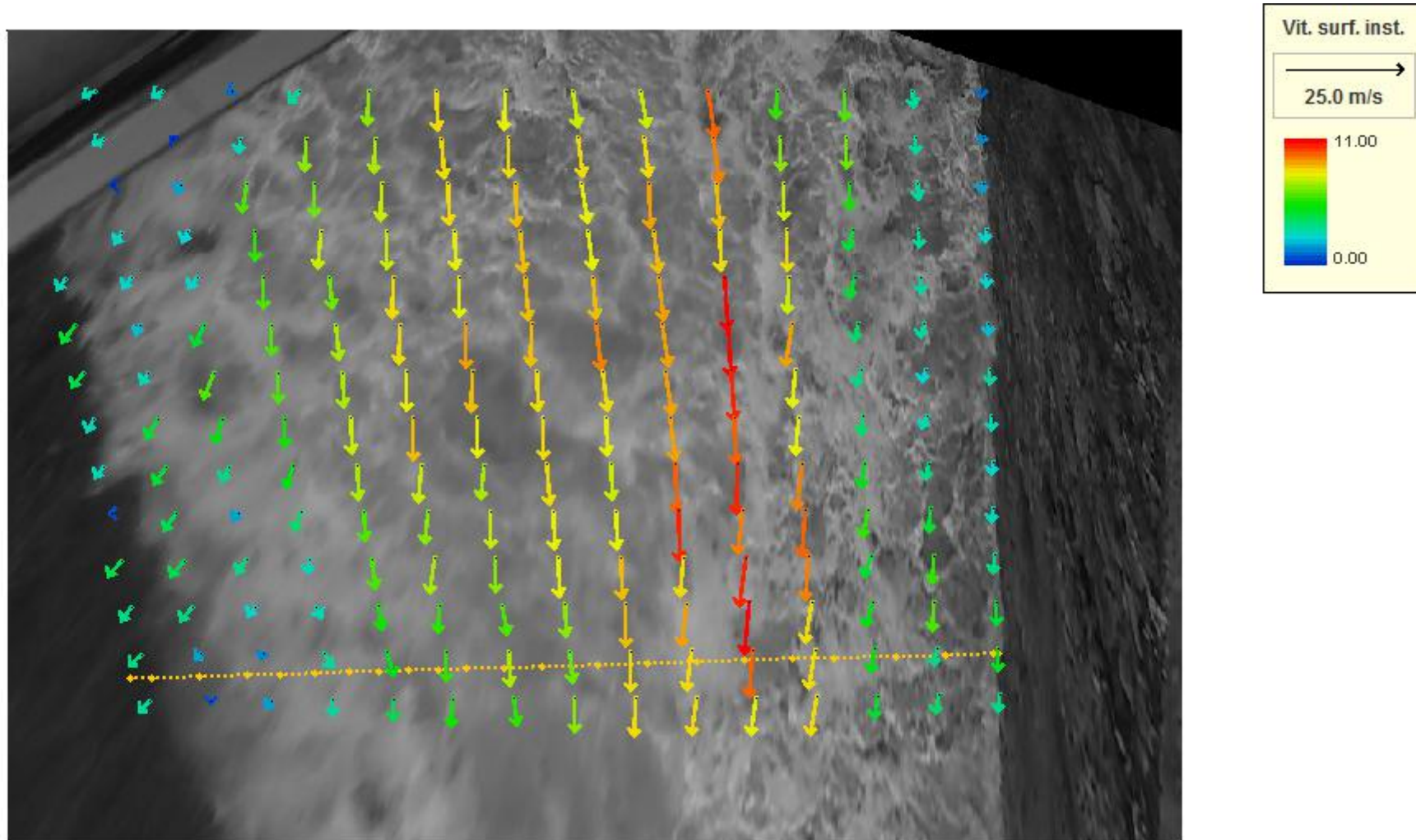
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #2



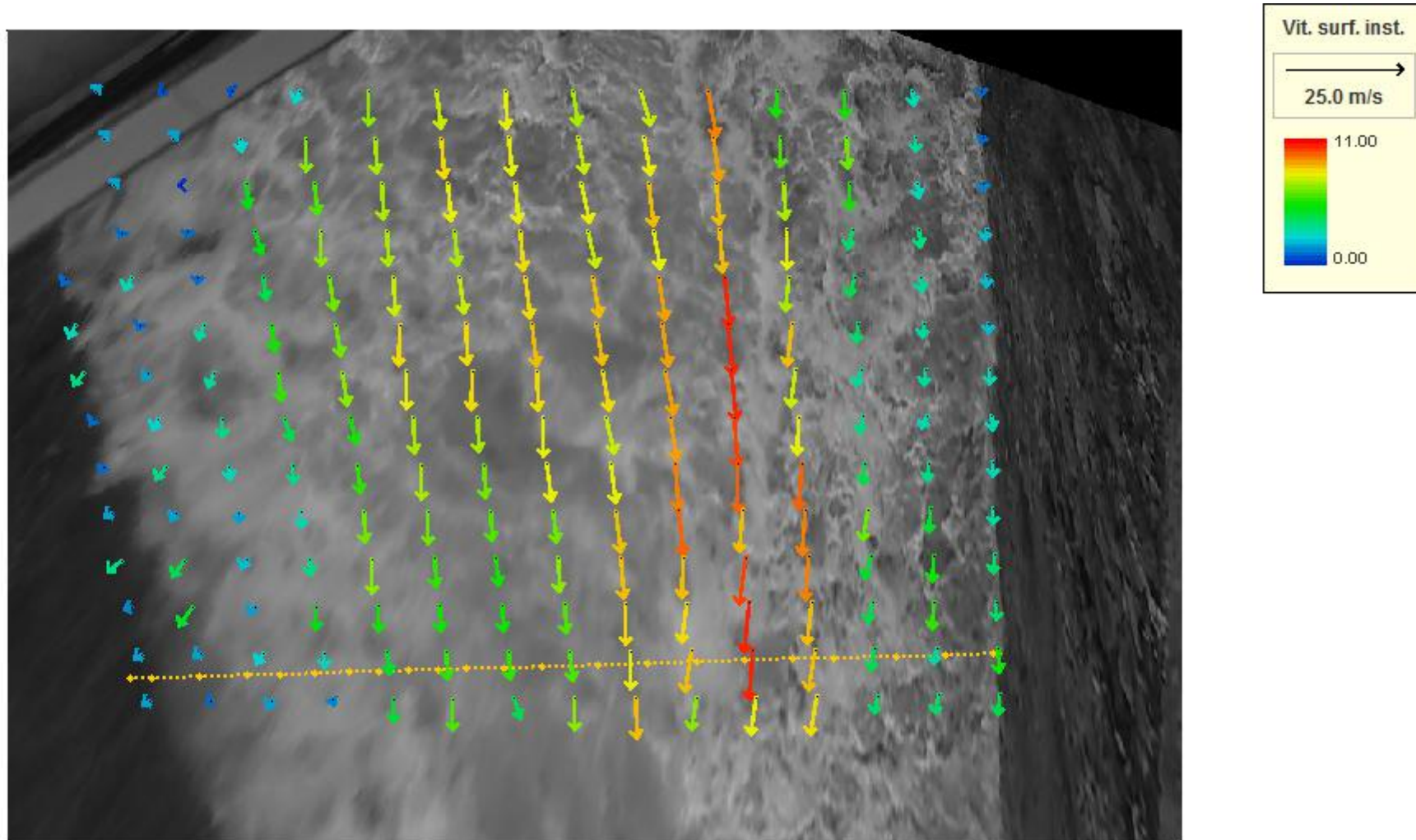
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #3



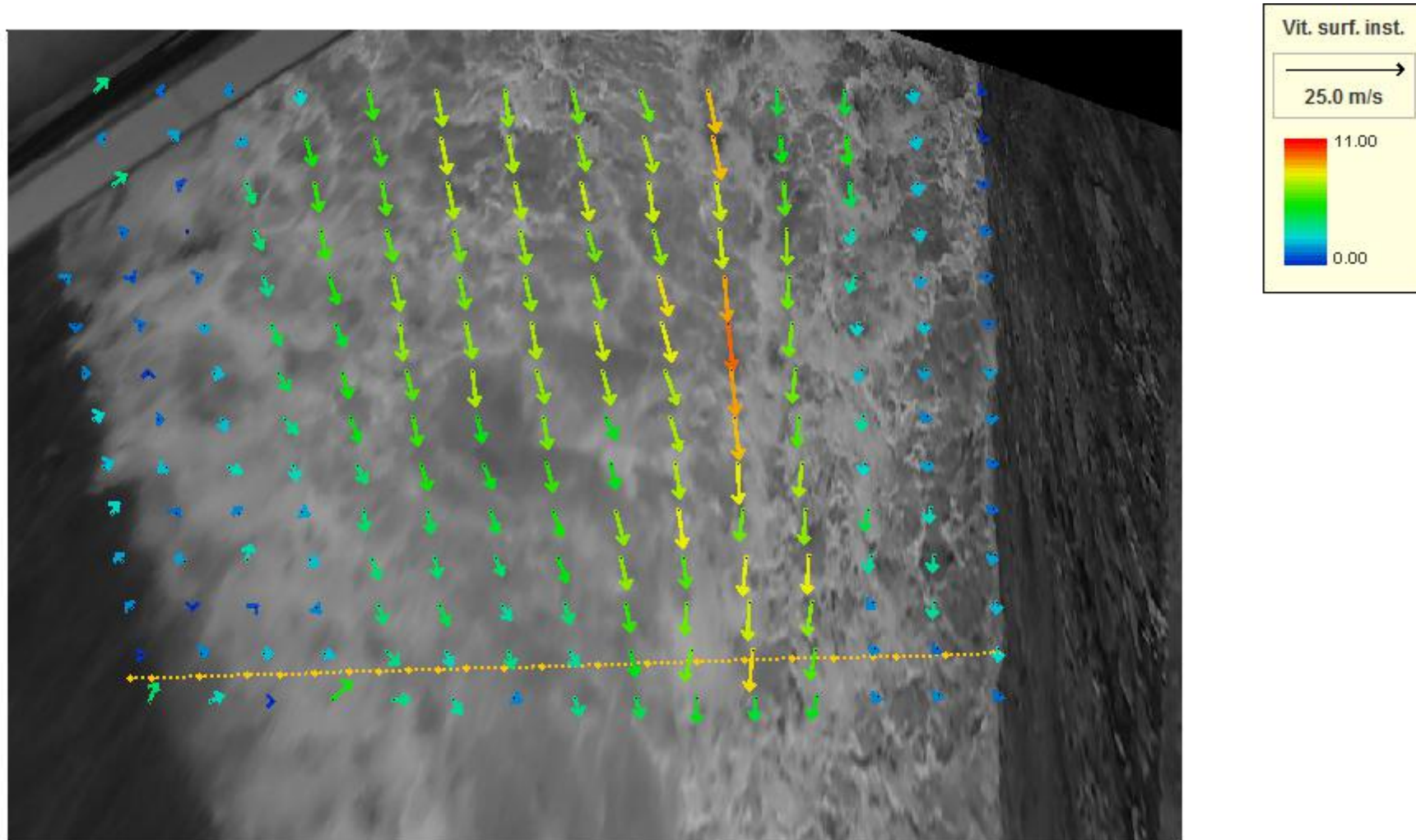
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #4



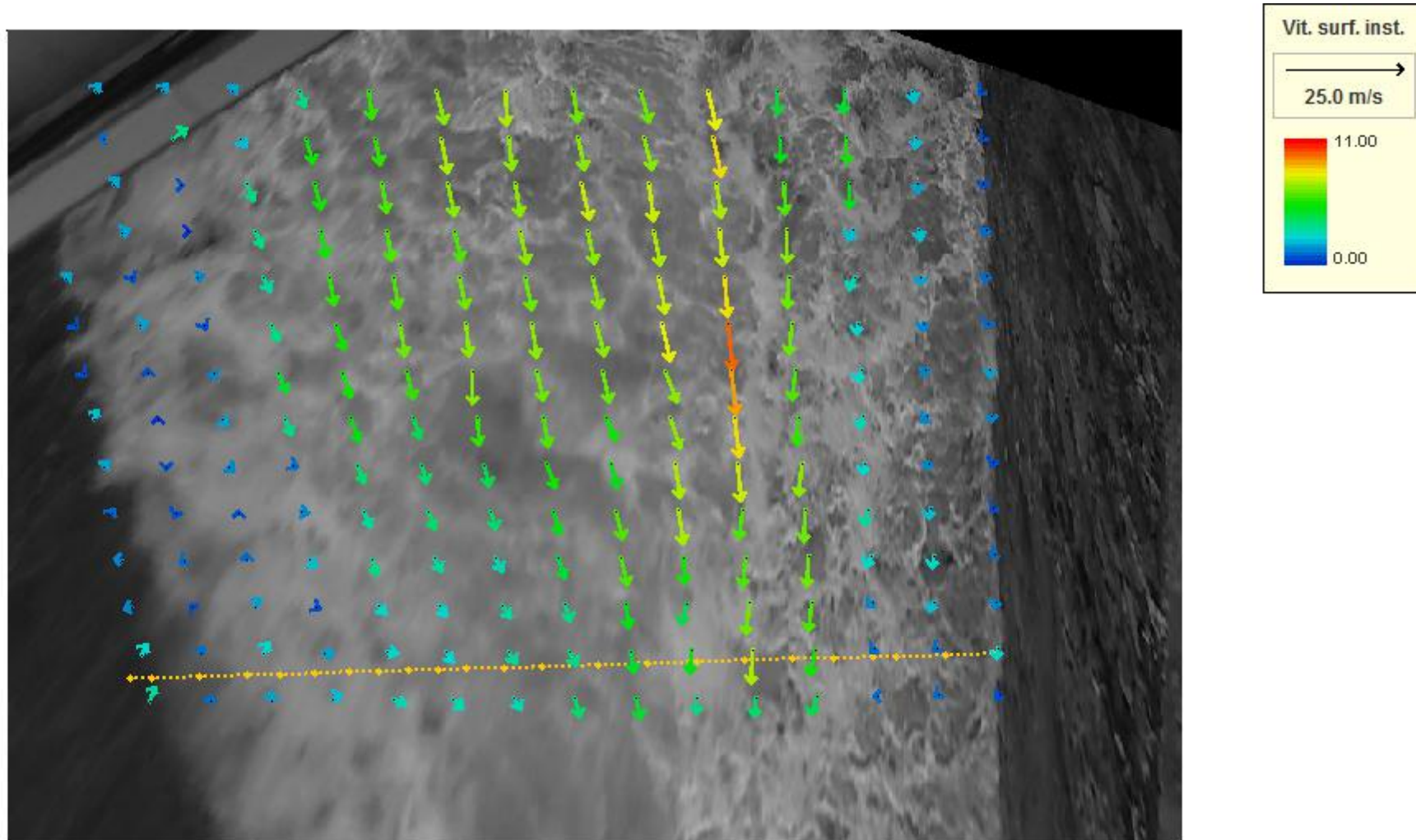
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #5



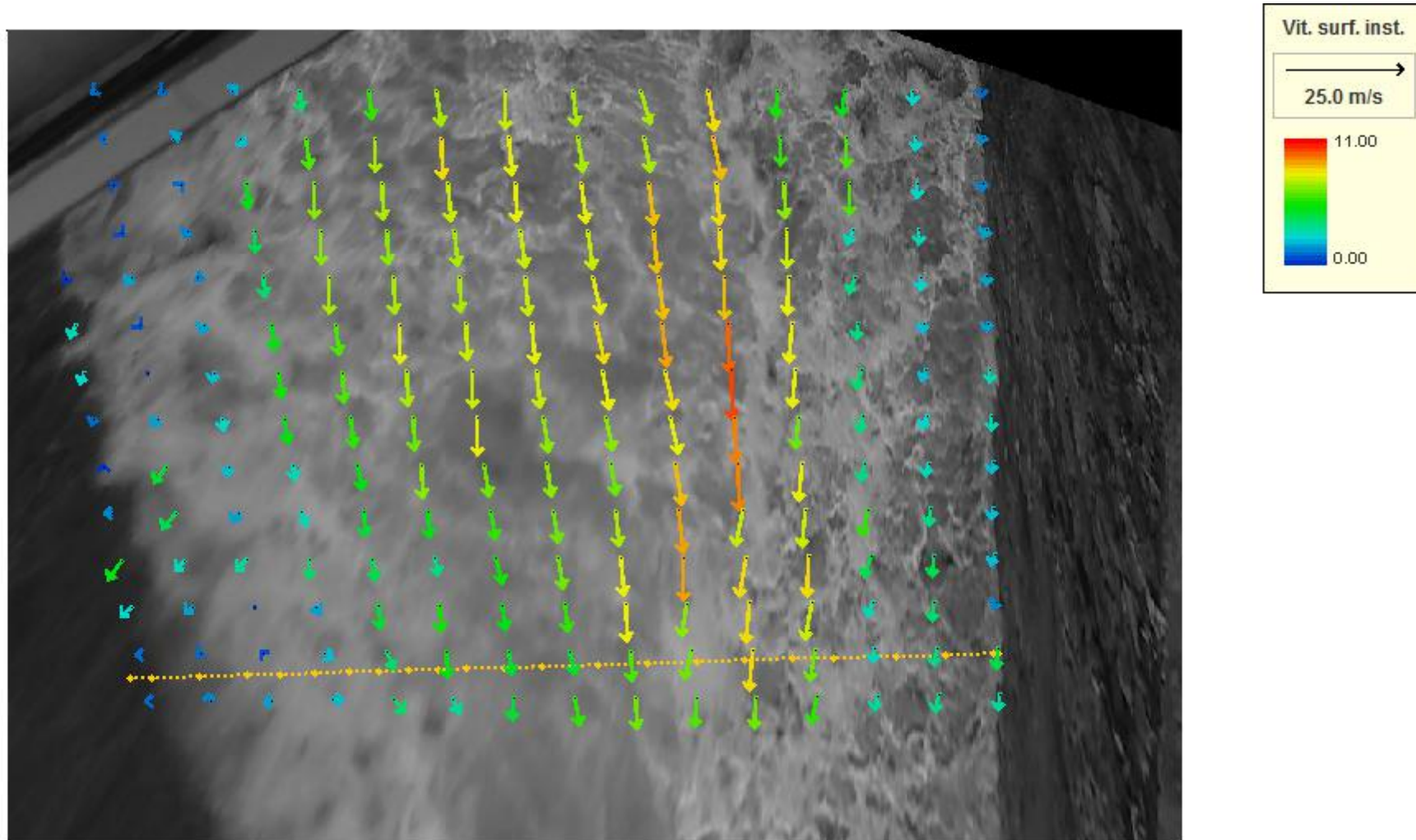
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #6



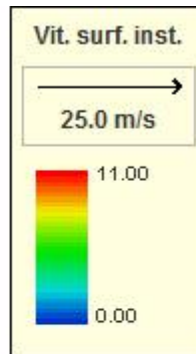
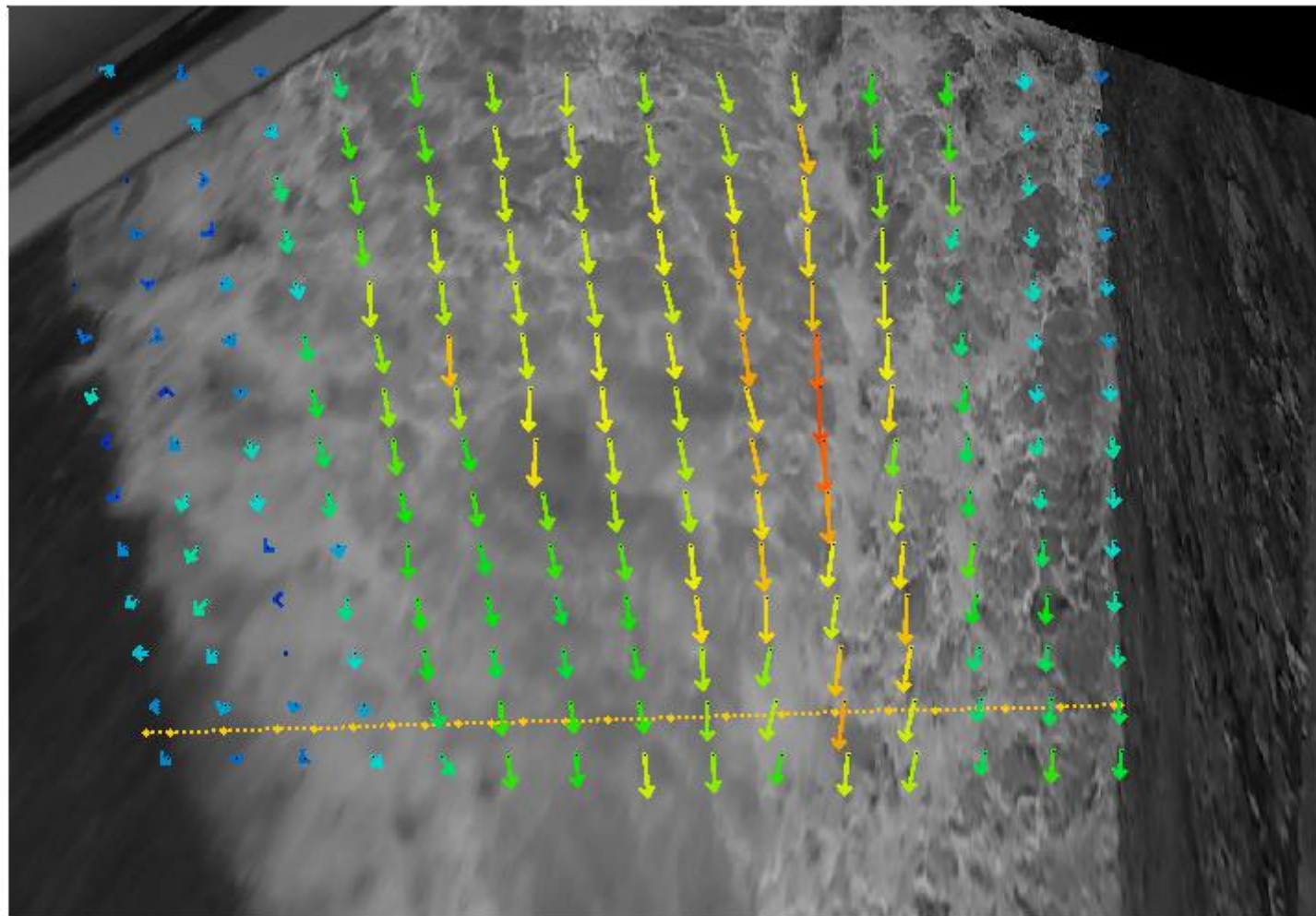
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #7



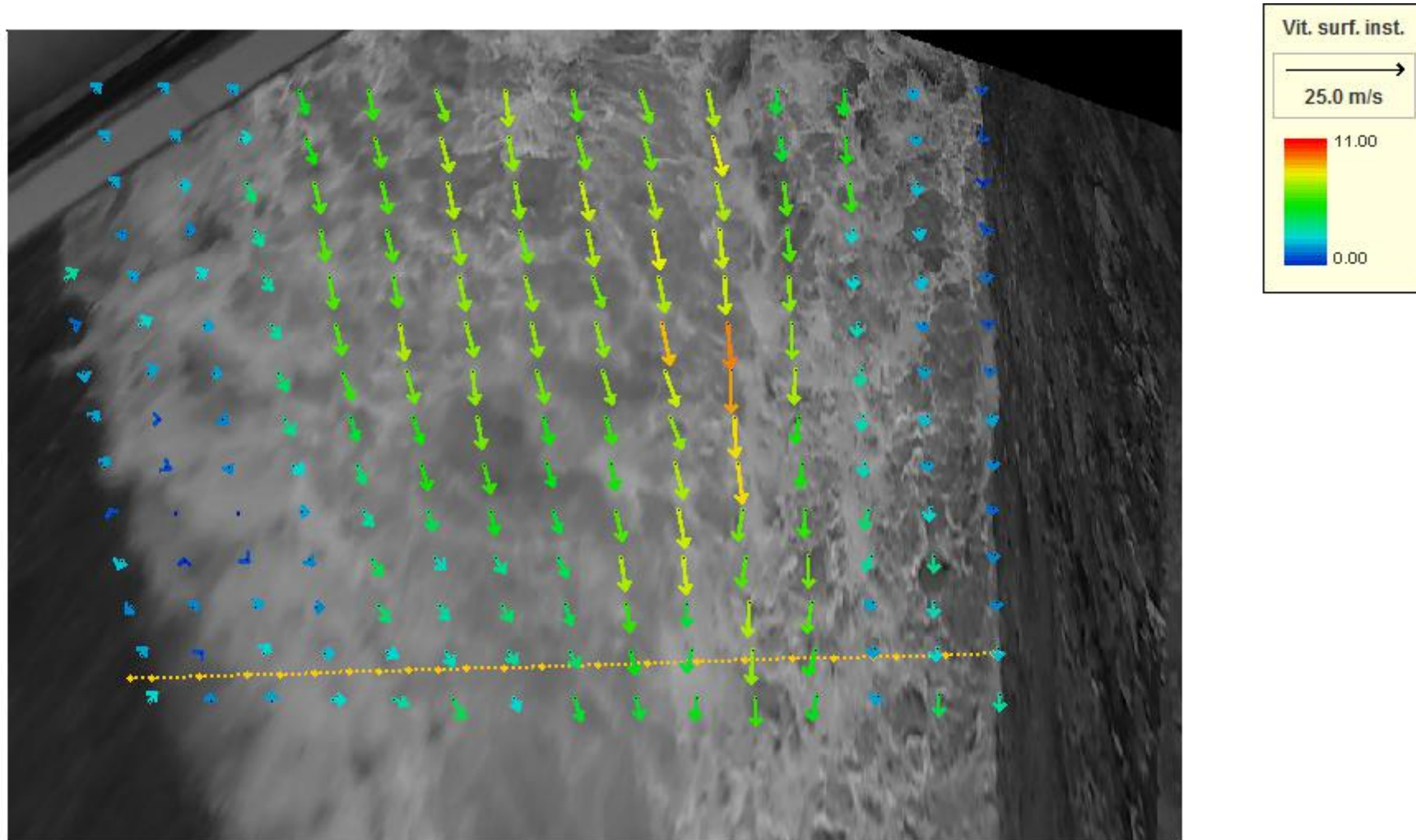
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #8



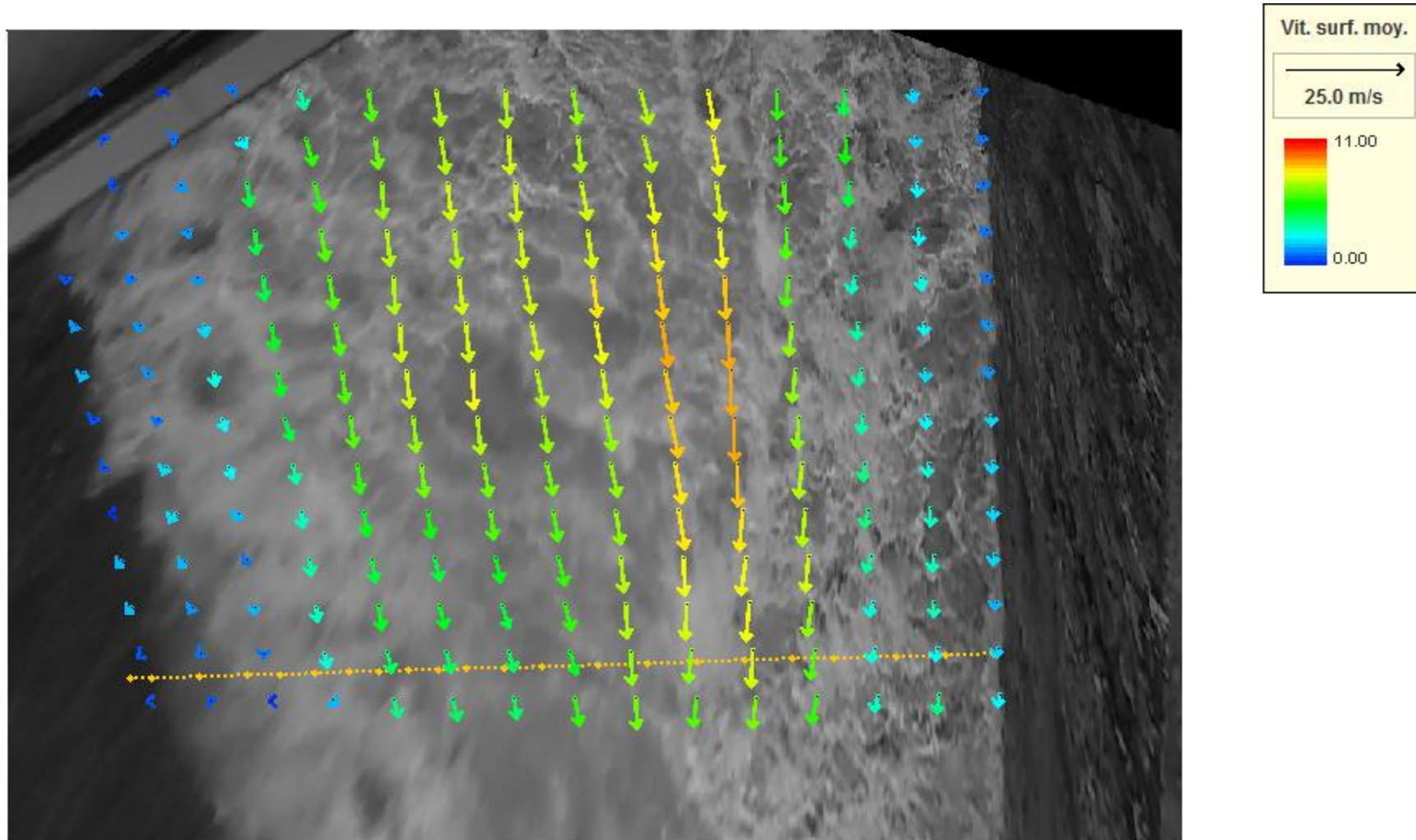
Field: flood streamgauging from YouTube home movies

Instantaneous velocity field and image #9

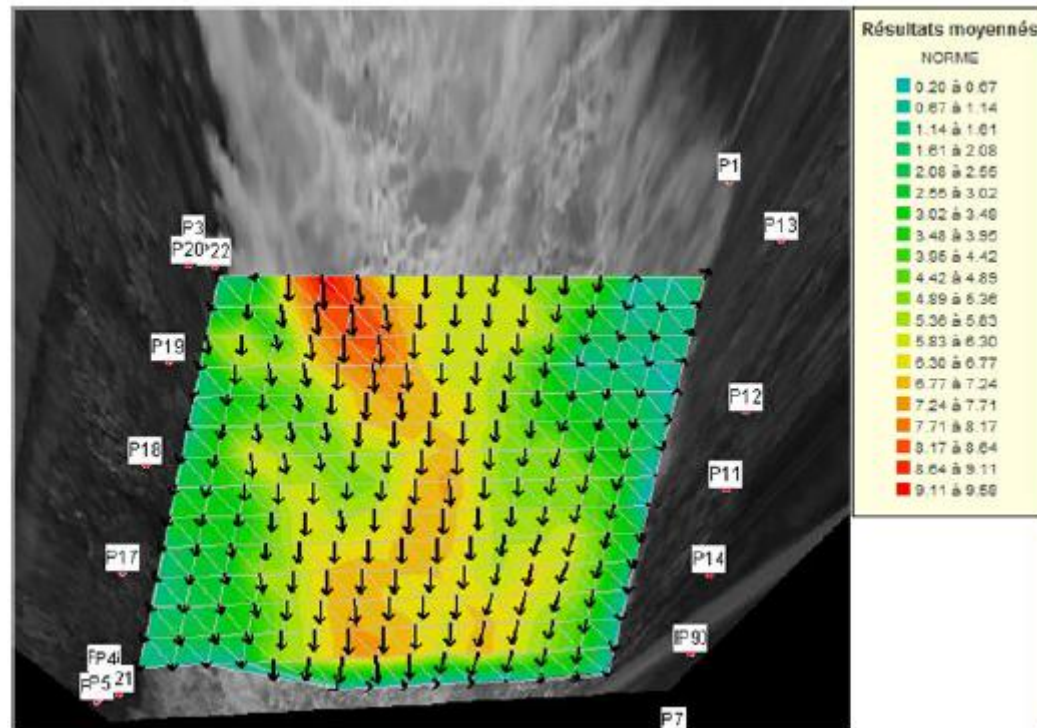


Field: flood streamgauging from YouTube home movies

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>

Etude des rivières en crue...

Vous pouvez nous* aider !



**En filmant quelques
secondes de l'événement
par tout moyen
à votre disposition**

(Smartphones, tablettes, appareil photo, etc...)

**sur la rivière ARDECHE
et ses affluents**

Objectif

La connaissance des débits
et des niveaux d'eau atteints
par les rivières en crue est
fondamentale pour l'étude
des crues éclair.

Malheureusement la
rapidité et la violence de ces
crues rendent les mesures
de débit quasiment
impossibles avec les
méthodes classiques.

Nous avons donc mis au
point des techniques
d'analyse d'images
permettant de calculer des
vitesses et des débits à
partir de films amateurs.

**Vous pouvez ainsi
contribuer à nos
travaux de
recherche en
filant les cours
d'eau en crue.**

Ces mesures seront
ensuite utilisées dans le
cadre du projet de
recherche ANR
FloodScale dont l'objectif
est de mieux comprendre
la formation des crues
éclair, et d'en améliorer la
modélisation.

Méthode

- Filmez la rivière sur toute sa largeur : les deux berges
de part et d'autre de la rivière doivent être visibles.
- Englobez dans l'image des repères fixes (coins de
bâtiment, panneaux de signalisation, fenêtres, ponts, etc.).
- La prise de vue doit être aussi stable que possible :
plans fixes, sans zoom ni mouvement de caméra.
- Filmez de préférence une zone sans remous ni vagues.
- Privilégiez un point de vue élevé : filmez plutôt depuis un
pont que depuis la berge (sans prendre de risque !).
- Tout type d'enregistrement vidéo est utilisable.
- Filmez au minimum 5 secondes par séquence.
- Indiquez le lieu, la date et l'heure de l'enregistrement.

Envoyez-nous vos films par lien de téléchargement* ou de visualisation (YouTube) à :
crues@irstea.fr
avec vos coordonnées et toute remarque concernant la crue observée

* Sites d'envoi de fichiers volumineux :

www.transfer.com www.dailymotion.com www.mega.co.nz

En savoir plus...

Consulter la vidéo exemple et en savoir plus sur l'analyse d'images
<http://floodscale.irstea.fr/ressources/vidéo-exemple-analyse-crue>



Observatoire Hydro-Météorologique
Méditerranéen Occident-Var
<http://www.ohmco.fr>

Projet HyMeX
<http://www.hy-mex.org>

Projet de recherche ANR FloodScale (2012-2015)
<http://floodscale.irstea.fr>



⚠ Avertissement sécurité ⚠

En cas de crues, l'accès aux abords des cours d'eau et aux ponts présente
des risques importants. Les conditions d'accès peuvent varier
rapidement en toutes circonstances. Ne vous aventurez jamais dans le lit d'un
cours d'eau ni sur ses berges. Respectez les consignes de sécurité et les
interdictions d'accès édictées par les autorités compétentes.

Observer ou filmer une crue ne justifie pas de prendre des risques !



* Chercheurs d'établissements
publics de recherche