
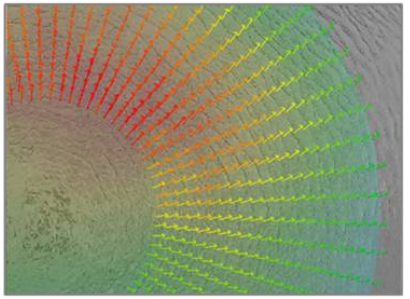


Quantifying the operator effect in LSPIV image-based velocity and discharge measurements

26 May 2022

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PhD: "Developments on the image-based method for surface velocity determination in open channel flows"

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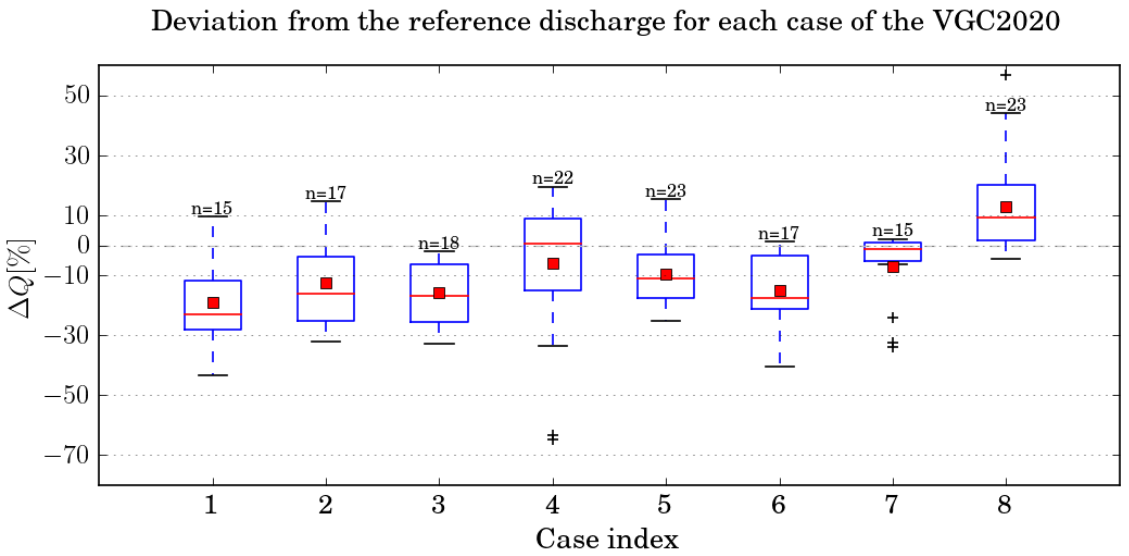
The operator effect in LSPIV (Large Scale Particle Image Velocimetry)

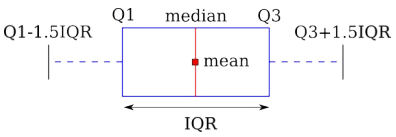
- LSPIV method is sensitive to its parameters
  - → Video sampling
  - → Ortho-rectification parameters
  - → Motion analysis parameters
  - → Filters
  - → (Discharge parameters)

- Sensitivity highlighted by a video gauging intercomparison: the Video Globe Challenge 2020

Video Globe Challenge 2020 (VGC2020)

- → 8 cases
- → ~20 participants with different levels of experience with LSPIV





n: number of participants

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Investigating the operator effect

- Analysis based on the Video Globe Challenge dataset
- LSPIV measurement were replayed (executables from Fudaa-LSPIV) and analysed
- Objectives :
  1) Identify the most sensitive parameter(s) for each case
  2) Review common operator mistakes
  3) Underline LSPIV MacGyver tricks

The Video Globe Challenge dataset

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Replaying LSPIV measurements

- Several **parameters** were **fixed** to ensure a meaningful comparison
  - Video sequencing (beginning and end of sequence)
  - Ground reference points (XYZ position, IJ indexes)
  - Grid for velocity computation

- The other **parameters** were **retrieved** from the **LSPIV gauging reports** submitted by the participants
  - Resolution of ortho-rectified frames [m/pix]
  - Time interval between frames (video sampling frame-rate)
  - PIV parameters
  - Velocity filters (vector based filters + correlation filter)
  - Discharge parameters (radius for surface velocity interpolation, surface coefficient)

- The **executable** from **Fudaa-LSPIV** were **used** to carry out the LSPIV analysis

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Analyzing the replayed LSPIV measurements

- A diagnostic was built for each step based on the following procedure:

  i. Analyse the deviation between the replayed discharge measurements and the original ones (i.e. submitted by the participants)

  ii. Analyse the velocity results with various graphics

  iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

  iv. Use forcing on parameter(s) to validate hypothesis (i.e. apply the same value to all participant and evaluate the impact on the deviation from discharge reference)

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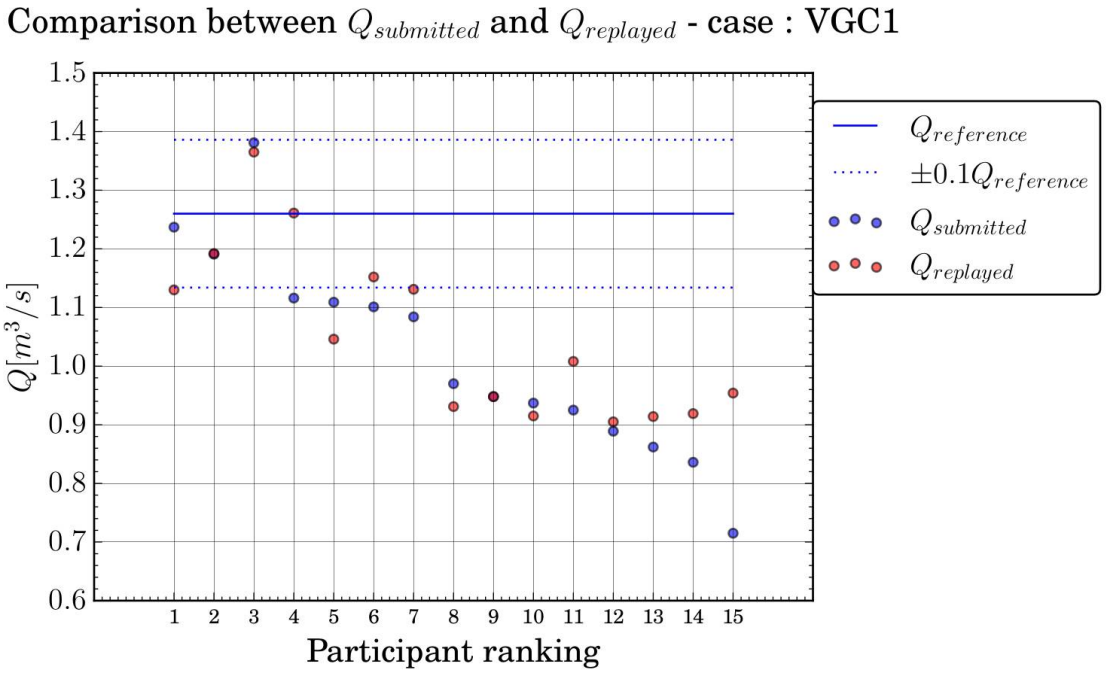
Analyzing the replayed LSPIV measurements

i. Analyze the deviation between the replayed discharge measurements and the original ones

- Deviation between $Q_{submitted}$ and $Q_{replayed}$ can be explained by difference in:
  - Video sequencing (beginning/end sequence)
  - Ground Reference Points pointing
  - Grid points positions



Example of comparison between replayed and submitted results, on the first case of the VGC2020

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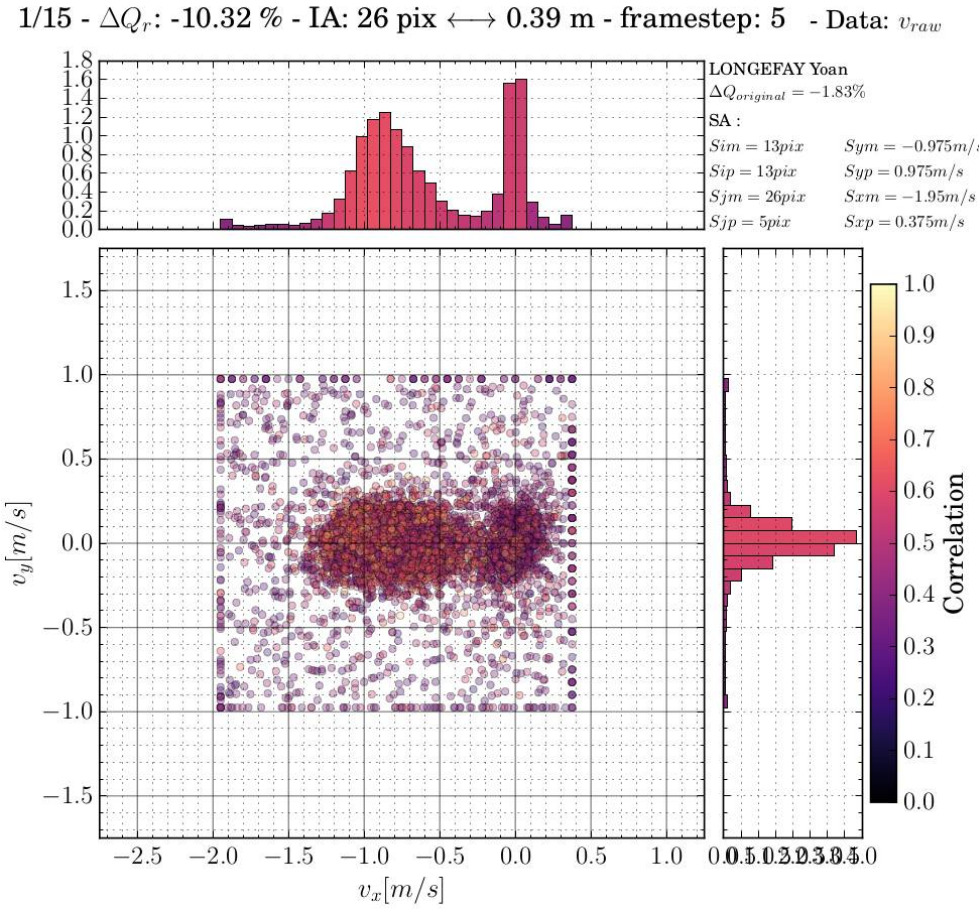
Analyzing the replayed LSPIV measurements

ii. Analyze the velocity results with various graphics

a) Scatter plot + histograms

- Represent the spatio-temporal velocity distribution
  - All grid points
  - All time steps
- Help to visualize the overall velocity distribution
- Link the velocity spatio-temporal distribution with parameters
- Either raw or filtered velocities can be investigated



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Analyzing the replayed LSPIV measurements

ii. Analyze the velocity results with various graphics

a) Scatter plot + histograms

1/15 → participant ranking

ΔQ_r: **-10.32 %** → Deviation between reference and replayed discharge

IA: 26 pix ⟷ 0.39 m → Interrogation Area size [pix] and [m]

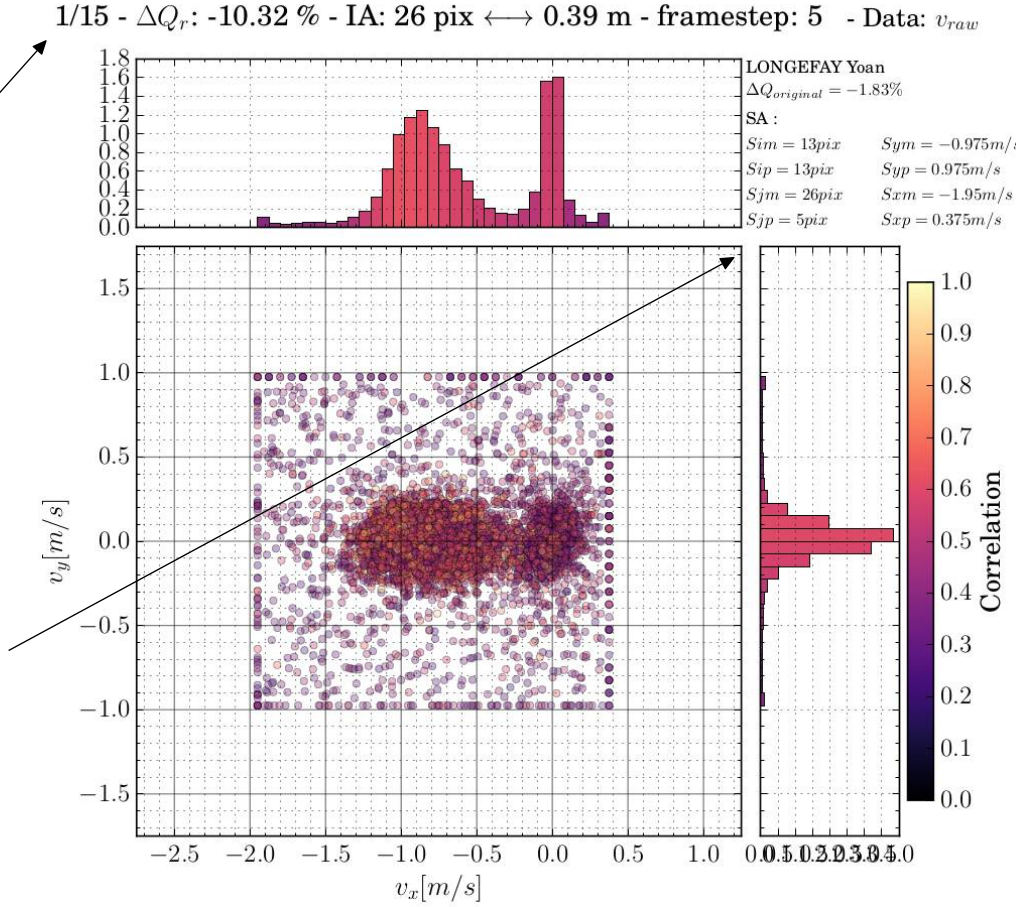
framestep: 5 → Video sub-sampling factor ($fps_{analysis} = fps_{source}$ / framestep)

LONGEFAY Yoan → participant name

$\Delta Q_{original} = -1.83\%$ → Deviation between reference and submitted discharge

$Sim = 13pix$ $Sym = -0.975m/s$
$Sip = 13pix$ $Syp = 0.975m/s$
$Sjm = 26pix$ $Sxm = -1.95m/s$
$Sjp = 5pix$ $Sxp = 0.375m/s$

→ Searching Area size [pix] and [m/s]



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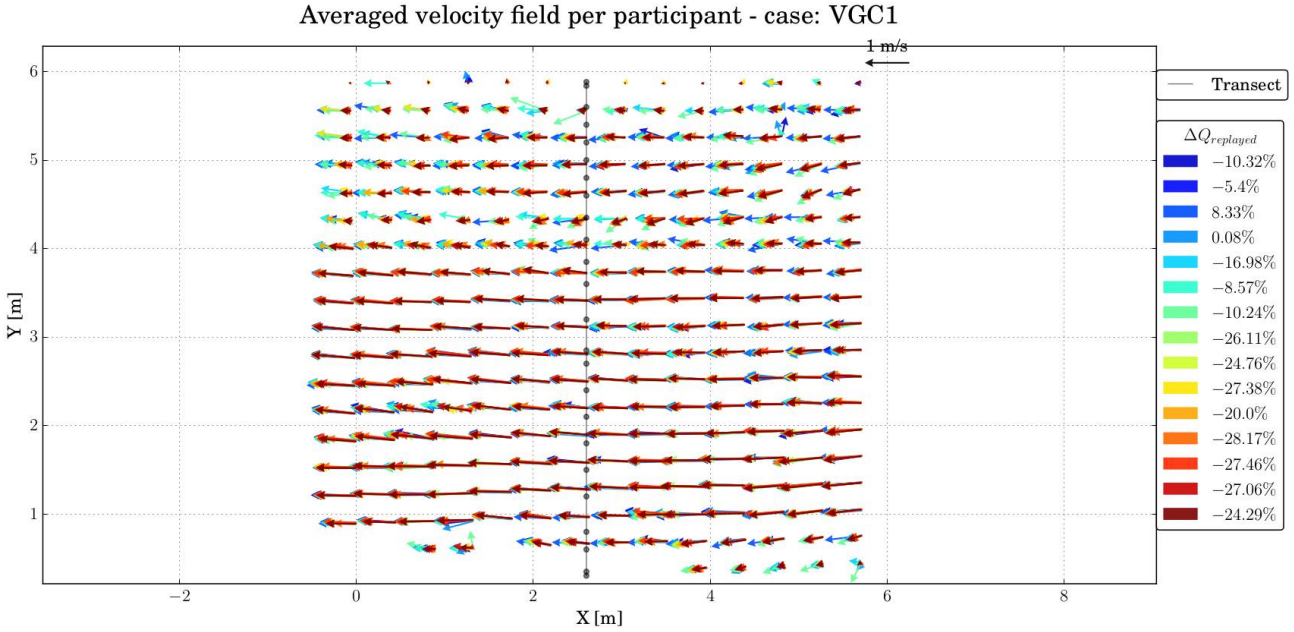
Analyzing the replayed LSPIV measurements

ii. Analyze the velocity results with various graphics

a) 2D averaged velocity field

- Represent the averaged surface velocity field of all participants
- The deviation between replayed and reference discharge is depicted in the legend
- Each colour is assigned to a participant
- → Help to identify areas with high velocity dispersion between users (possible sources of errors)



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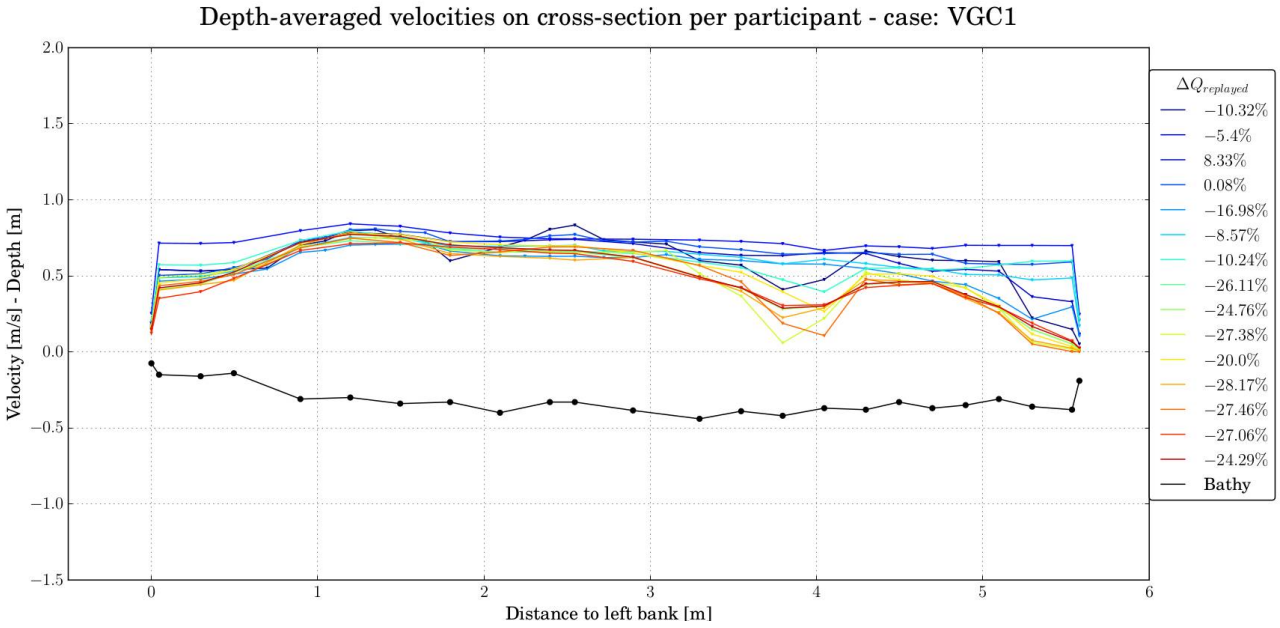
Analyzing the replayed LSPIV measurements

ii. Analyze the velocity results with various graphics

a) Transect velocities

- Represent the depth-averaged velocities along the transect, for all participants
- The deviation between replayed and reference discharge is depicted in the legend
- Each colour is assigned to a participant
- → Help to identify areas with high velocity dispersion between users (possible sources of errors)



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Analyzing the replayed LSPIV measurements

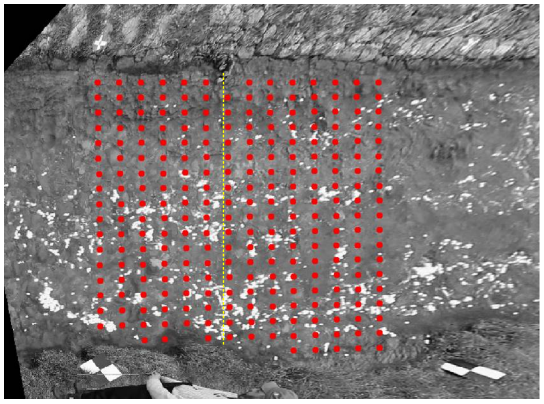
iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)

- Characteristics:
  - Low velocities (~1m/s)
  - Artificial seeding → spatio-temporal variation of tracers density
  - Clear water → potential near-zero velocities due to the apparent bed movements caused by water refraction

- 2D ortho-rectification with 4 points

  Calculation grid and transect printed on ortho-rectified frame →



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Analyzing the replayed LSPIV measurements

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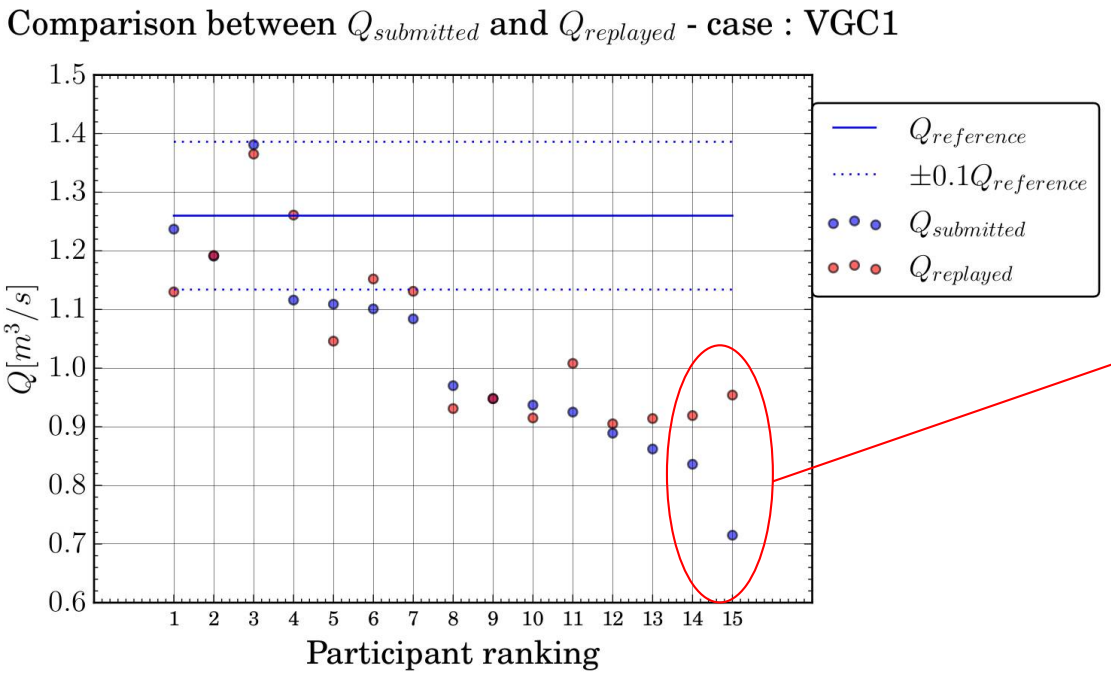
Example of the case VGC1 : La Vence @ Saint Egrève (France)



- Origin of deviation between submitted and replayed discharge
  - → Video sequencing: study window is too long for these participants
    - → Analysis before the appearance of artificial tracers
      - → Transparent water → near-zero velocities (movement of the bed due to water refraction)

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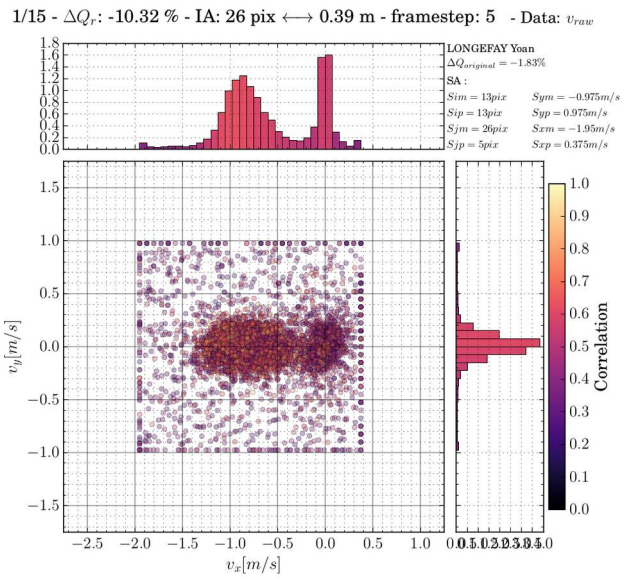
Analyzing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

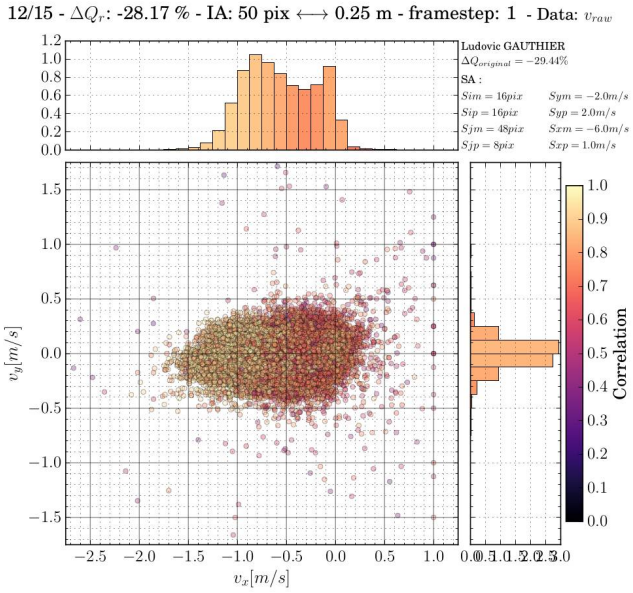
Example of the case VGC1 : La Vence @ Saint Egrève (France)

- Segmentation of displacement populations helped by
  - → a correct time interval
  - → a correct filtering

- 4 fps (1/5 source)



- 20 fps (1/1 source)



Raw results of two participants (1st and 12th)

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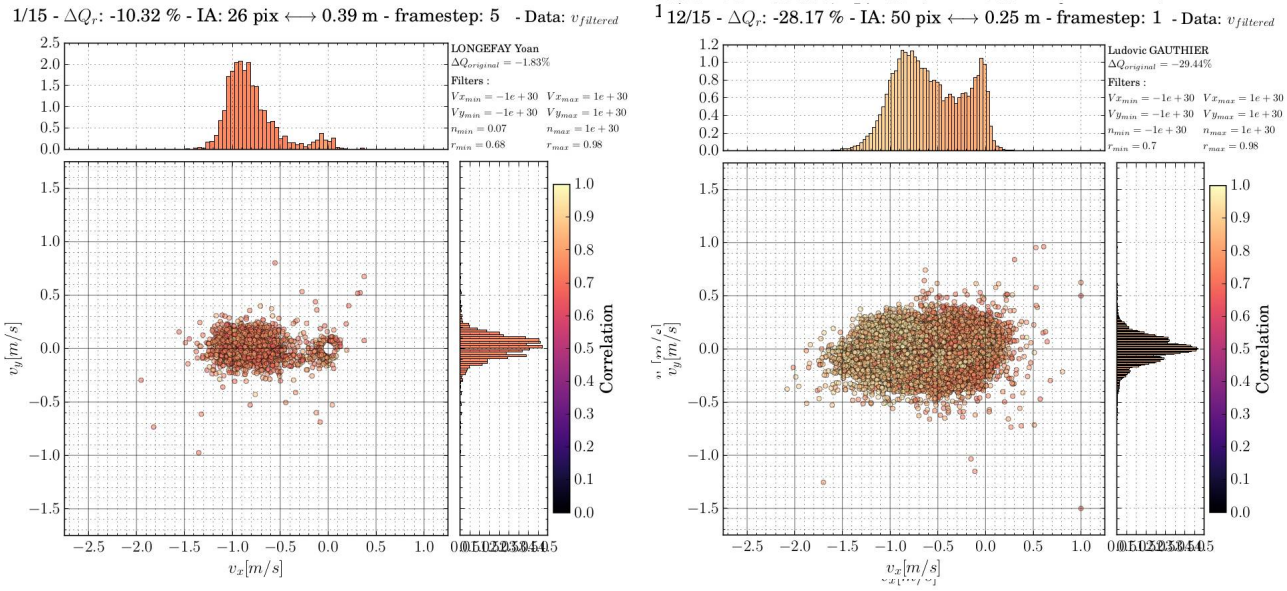
Analyzing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)

- Segmentation of displacement populations helped by
  - a correct time interval
  - a correct filtering

- 4 fps (1/5 source)
- 20 fps (1/1 source)



Filtered results of two participants (1st and 12th)

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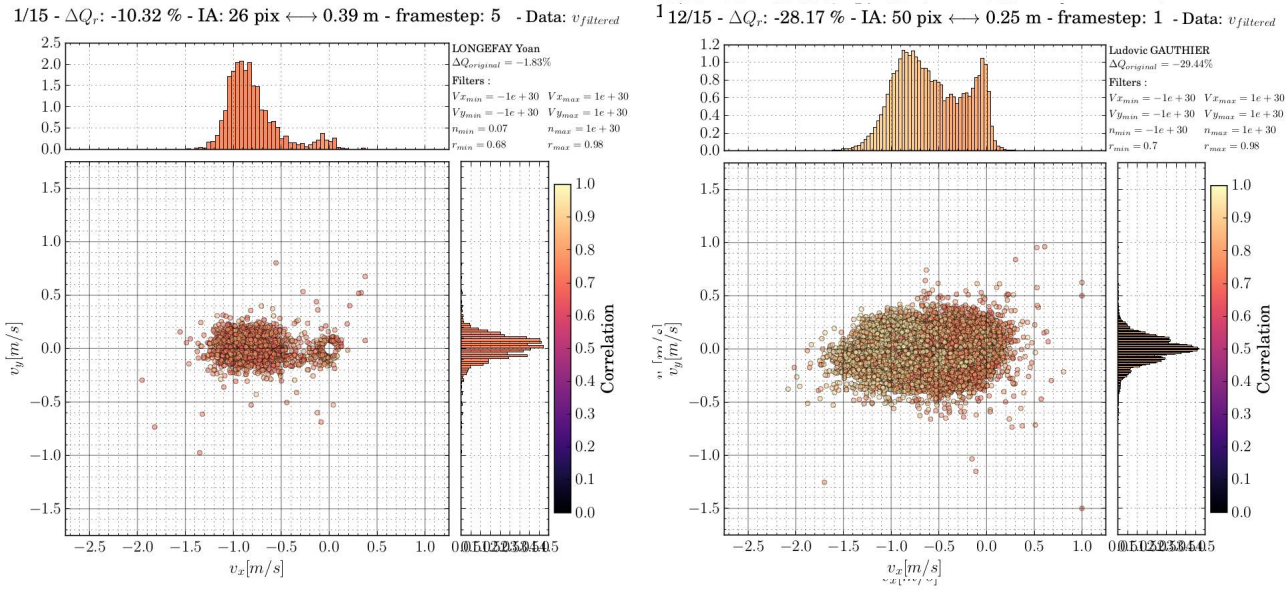
Analyzing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)

- Segmentation of displacement populations helped by
  - a correct time interval
  - a correct filtering
- Near-zero velocities were not correctly filtered for participant B (right). This explains the stronger negative bias on the measured discharge

- 4 fps (1/5 source)
- 20 fps (1/1 source)



Filtered results of two participants (1st and 12th)

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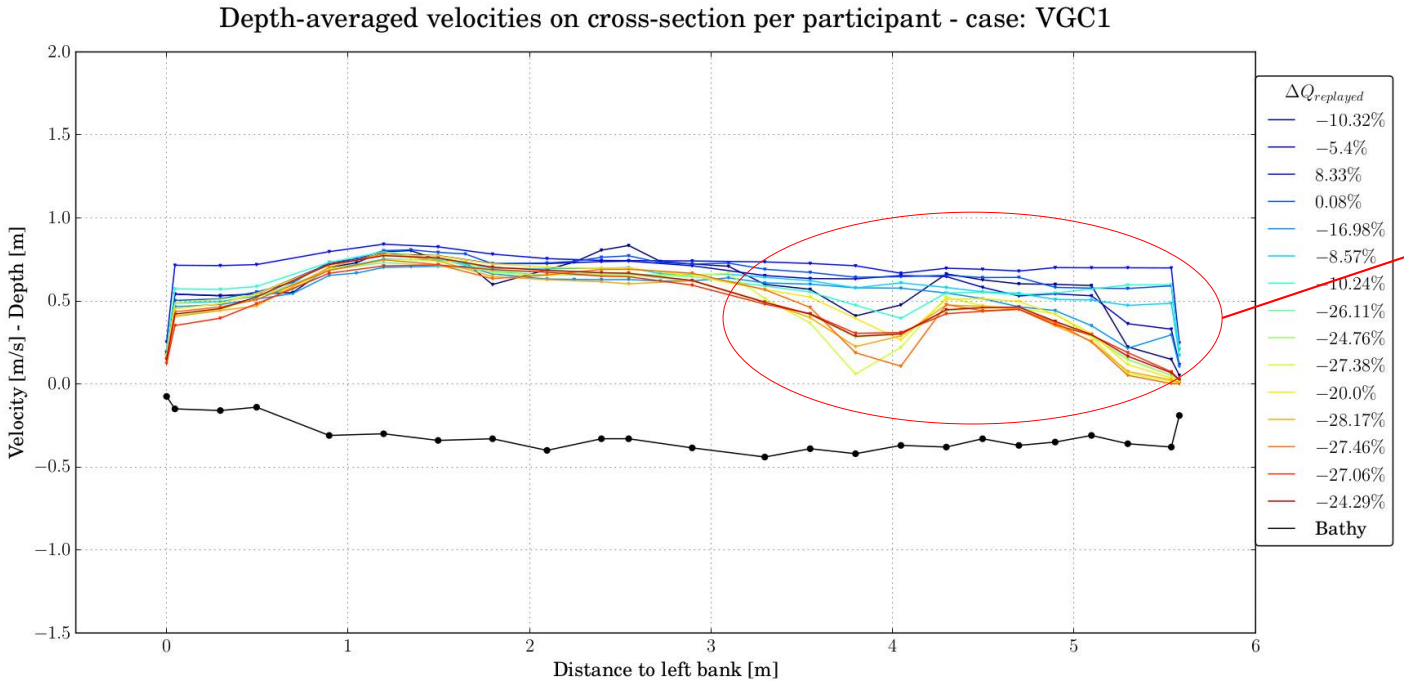
Analysing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)



- It seems that velocities on the right side of the flow were mostly under-estimated by several participants

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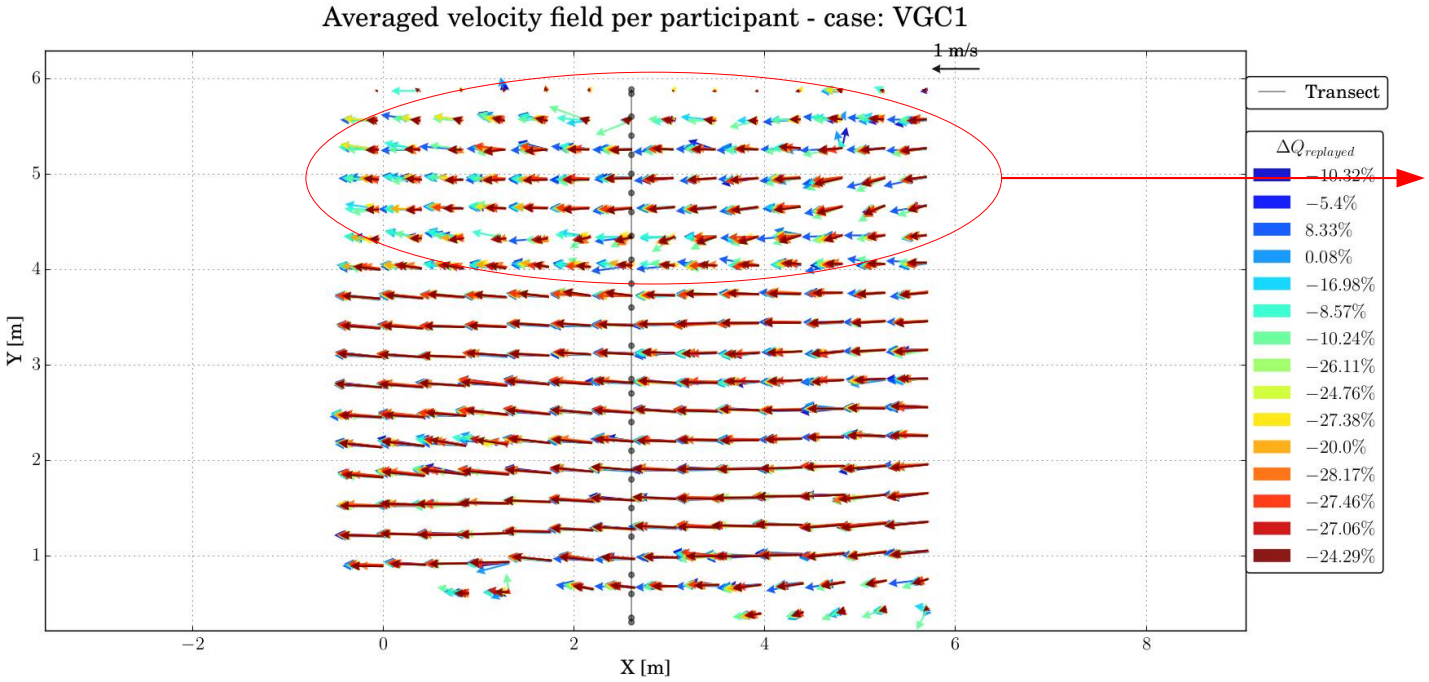
Analyzing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)



- It seems that velocities on the right side of the flow were mostly under-estimated by several participants

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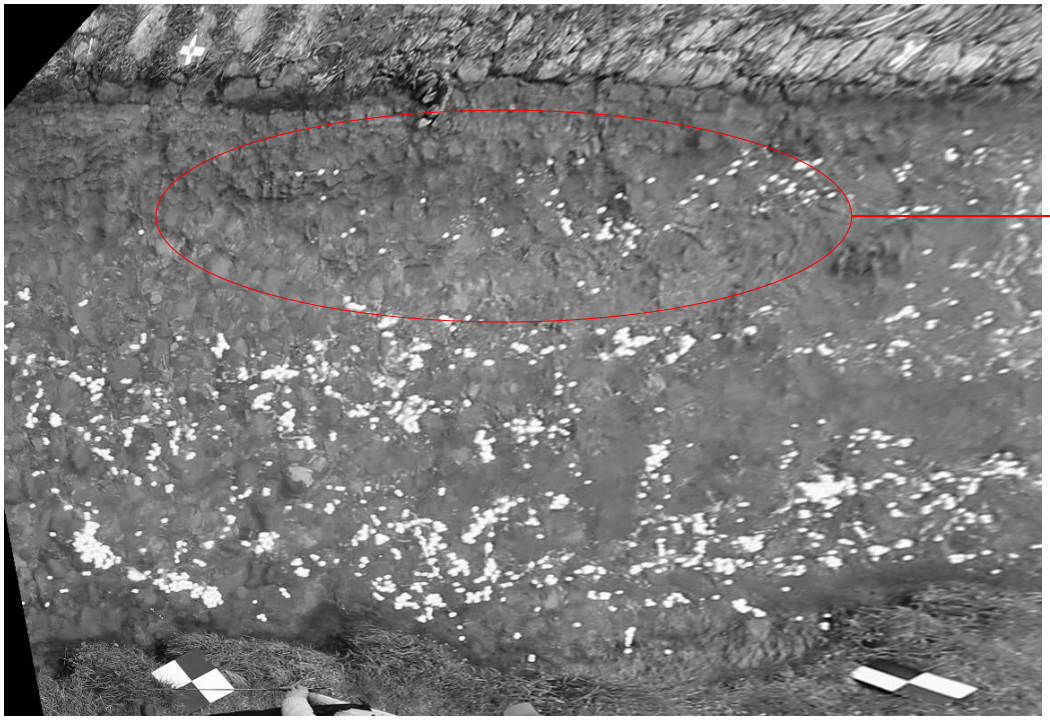
Analyzing the replayed LSPIV measurements

iii. Link errors with parameters and error source (water aspect, tracers type/density, user mistake)

Example of the case VGC1 : La Vence @ Saint Egrève (France)



- This is due to the low seeding density which vary through time
- Near-zero velocities corresponds to the river bed apparent movements due to water refraction
- A correct time interval helped to filter out these velocities

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Analyzing the replayed LSPIV measurements

iv. Use forcing on parameter(s) to validate hypothesis (i.e. apply the same value to all participant and evaluate the impact on the deviation from discharge reference)

Example of the case VGC1 : La Vence @ Saint Egrève (France)

- A minimum video subsampling factor was imposed to the participants
  - The obtained frame-rate ensures a minimum mean displacement of 3 pix:

$$n_{mean} > 3\,pix$$

- Several filters were imposed:
  - $r_{min} = 0.65$
  - $n_{min} = 0.1$
  - $n_{max} = 2$
  - $Vx_{max} = 0$

- This replayed dataset is named $Q_r|_{minDt+filters}$

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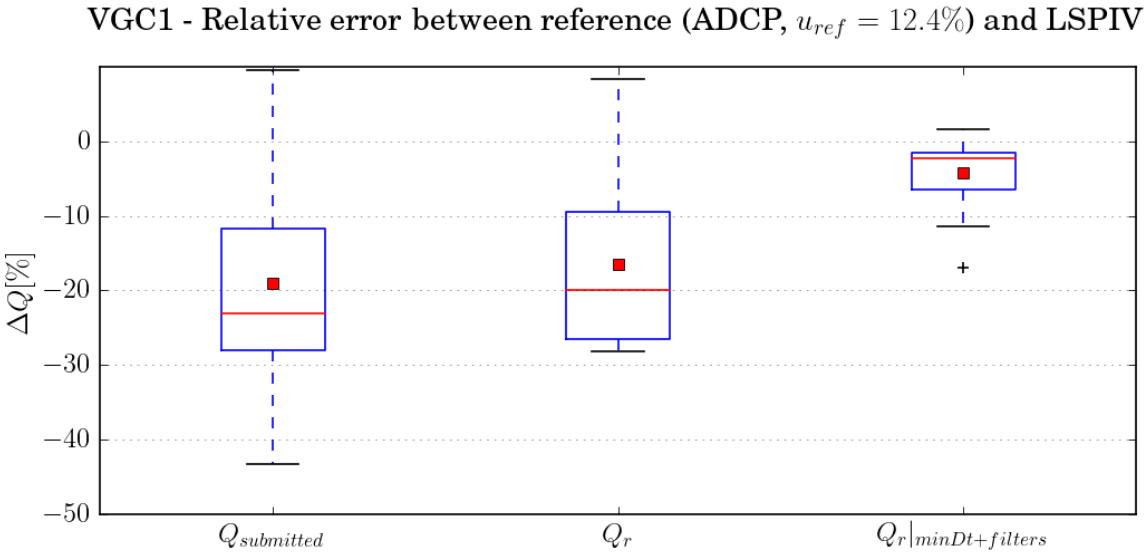
Analyzing the replayed LSPIV measurements

iv. Use forcing on parameter(s) to validate hypothesis (i.e. apply the same value to all participant and evaluate the impact on the deviation from discharge reference)

Example of the case VGC1 : La Vence @ Saint Egrève (France)



- Strong **reduction** of the **relative error** with the **reference**
- Strong **reduction** of the **dispersion** of **measurement**

➔ This confirms the **impact** of the **time interval** and the **filtering step** on the measurement, in this particular case

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Investigation on the sensitivity of each case of the VGC 2020

Case #1

- Particularities
  - Low tracer density on the right side of the flow
  - Water transparency
  - Low velocities
  - 2D ortho-rectification

- Sensitive parameter(s)
  - Time interval
  - Filters

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Investigation on the sensitivity of each case of the VGC 2020

- Sensitive parameter(s)
  - Time interval
  - Filters

Case #2

- Particularities
  - Far distance
    - Low displacements
  - Tracers density and quality vary spatially
  - Scaling (no ortho-rectification)

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Investigation on the sensitivity of each case of the VGC 2020

Case #3

- Particularities
  - Oblique point of view
  - 3D ortho-rectification
  - Almost pipe flow under the bridge down-stream

- Sensitive parameter(s)
  - Surface coefficient
    - Correct value: 1.06

- In this case **errors** are mainly **due** to a **user mistake**: **wrong surface coefficient** applied.

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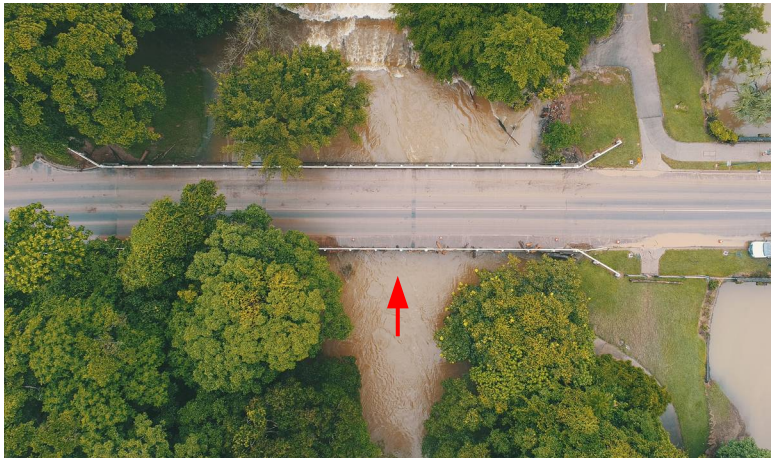
Investigation on the sensitivity of each case of the VGC 2020



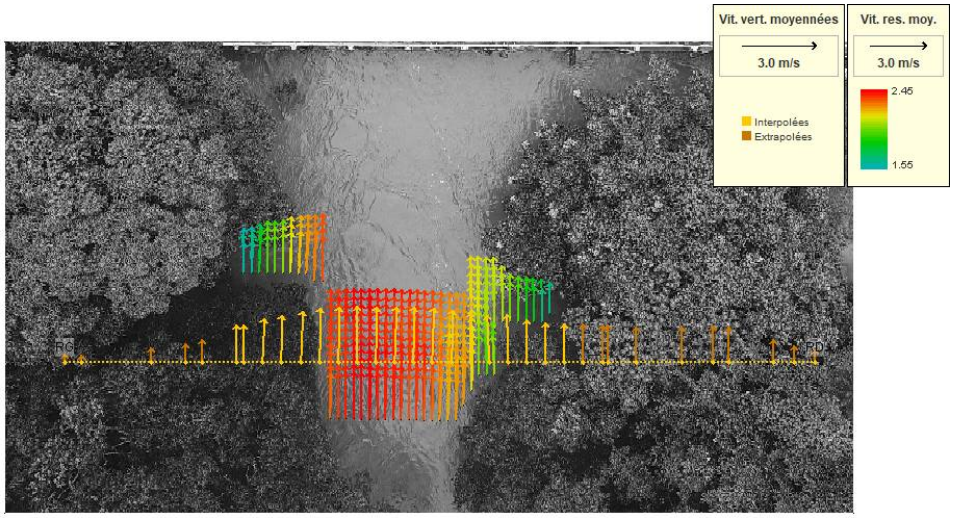
Case #4

- Particularities
  - Far distance
  - Hidden parts of the flow (trees)
  - Scaling (no ortho-rectification)

- Sensitive parameter(s)
  - Grid

- LSPIV MacGyver tricks

  - **Add grid points** in visible areas between trees
  - **Adapt interpolation radius** for surface velocity determination on transect



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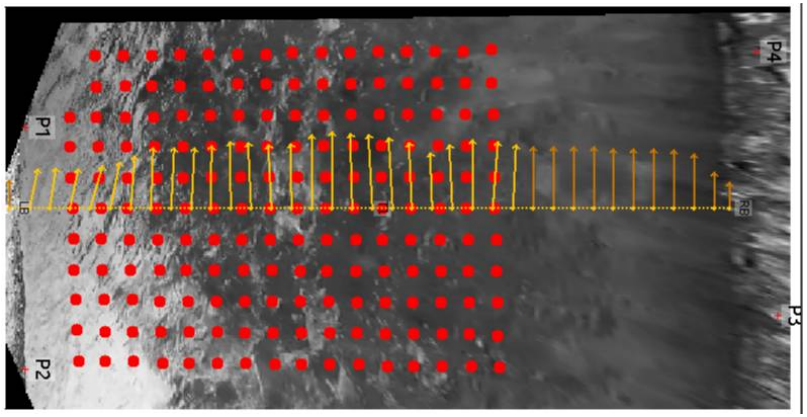
Investigation on the sensitivity of each case of the VGC 2020

Case #5

- Particularities
  - Low tracer density on right side of the flow (shadows)
  - Oblique point of view
  - 2D ortho-rectification

- Sensitive parameter(s)
  - Grid
  - Filters
- LSPIV MacGyver tricks →

- **Truncate grid** to prevent PIV errors due to low contrasted surface on right side
- Rely on **transect velocity extrapolation**



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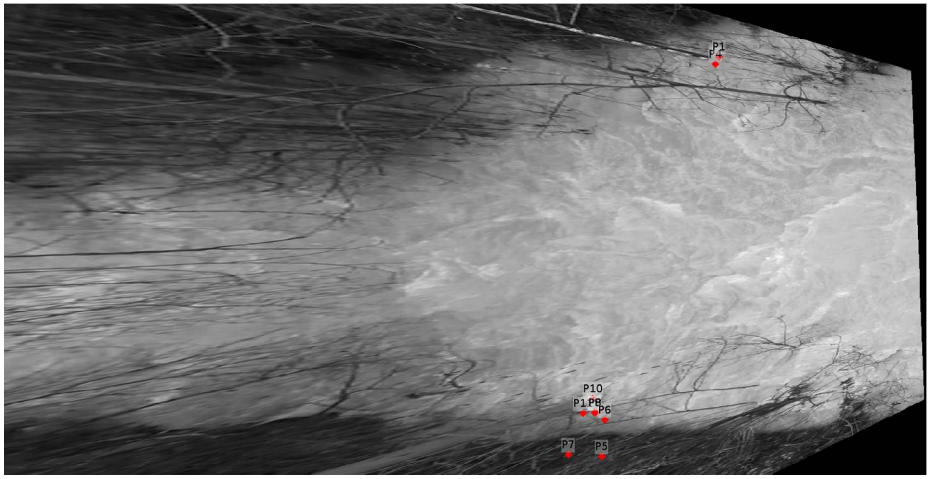
Investigation on the sensitivity of each case of the VGC 2020

Case #6

- Particularities
  - → 3D ortho-rectification

- Sensitive parameter(s)
  - → Ground Reference Points pointing
    - → Poor spatial distribution (XY-space) of the GRPs
      → High sensitivity to the errors of pointing



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Investigation on the sensitivity of each case of the VGC 2020

Case #7

- Particularities
  - Sun reflections
  - Far distance
    - Low displacements
  - Areas with poor tracers density
  - Scaling (no ortho-rectification)

- Sensitive parameter(s)
  - Time interval
  - Grid
  - Filters

- In this case the **grid points** are very **important**. If a grid **point** is set in an **area** with **poor contrast** or static objects (e.g. right bank) **measurement errors** can occur.

  These **errors** are **difficult** to **filter** out as correlation can still be high.

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Investigation on the sensitivity of each case of the VGC 2020

Case #8

- Particularities
  - Volatile tracers
  - High displacements
  - Recirculation (rocks on the right side)
  - 2D ortho-rectification

- Sensitive parameter(s)
  - Grid
  - Filters

- Surface **tracers** are very **fickle** which generates many **spurious vectors**.
- The **recirculation** implies that **many vector directions** can be found within the vector field. As a consequence, **vector-based filtering** is **limited**.

  Thus, many **spurious vectors remain unfiltered** and affect the velocity results.

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Parameters wizard

- Assistance tools proposed to contain errors
  - ➔ Pre-processing tools used to help the user to set up the parameters
  - ➔ Post-processing tools used to ensure robustness of the measurement
- Validation of the various tools on the VGC dataset
- Assistance tools (AT) :
  - Automated time interval (video sub-sampling)
    - ➔ Sub-sampling factor ensuring a mean displacement magnitude of 3 pixels between the two first frames
  - Temporal coherency
    - Temporal filtering
      - ➔ Filter velocities at a point with a threshold at 2σ from μ
    - Median velocity used instead of mean velocity
  - Spatial coherency
    - Median test (Westerweel & Scarano 2005)

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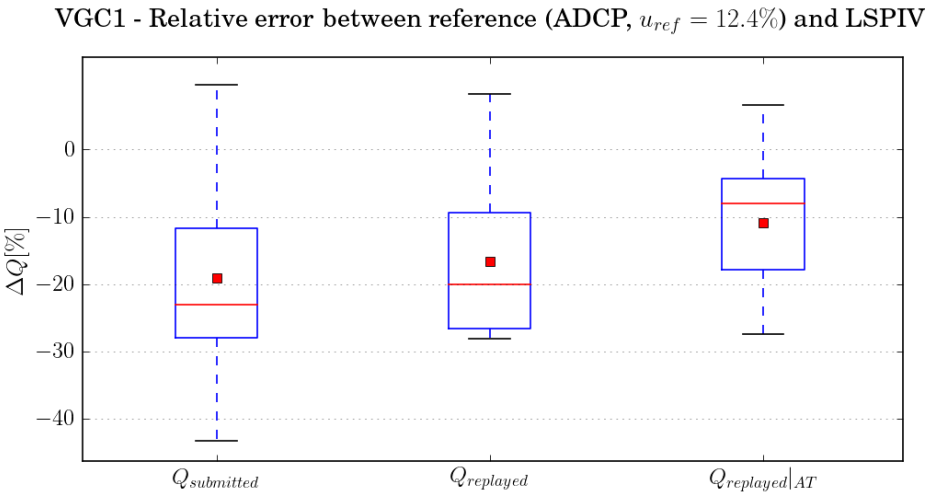
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #1

- Particularities
  - Low tracer density on the right side of the flow
  - Water transparency
  - Low velocities
  - 2D ortho-rectification



- Discharge **errors reduced** with assistance tools
  - Results can be improved more by playing with the median test parameters

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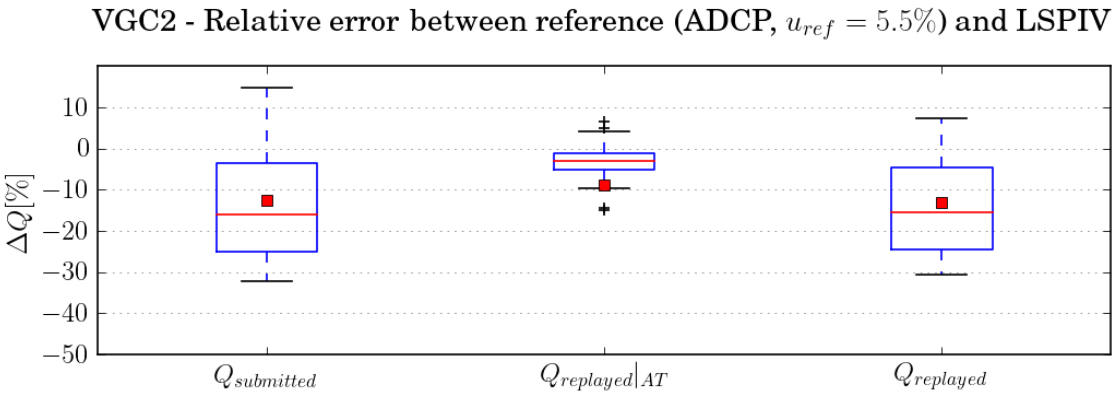
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #2

- Particularities
  - Far distance
    - Low displacements
  - Tracers density and quality vary spatially
  - Scaling (no ortho-rectification)



- Discharge **errors strongly reduced** with assistance tools

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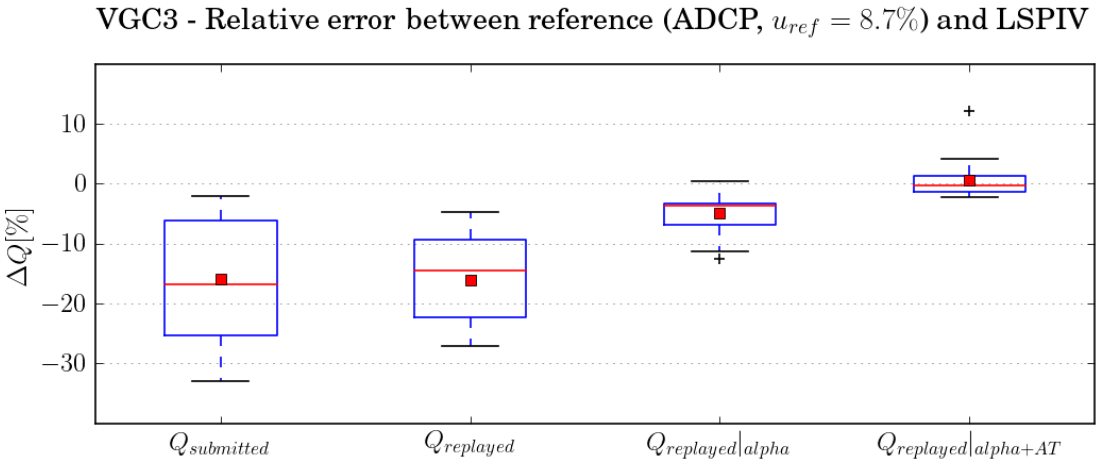
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #3

- Particularities
  - Oblique point of view
  - 3D ortho-rectification
  - Almost pipe flow under the bridge down-stream



- Results are also replayed with a correct surface velocity coefficient (alpha = 1.06)
  - Strong reduction of discharge errors
- Deviation with the reference is reduced to ~1% with the assistance tools

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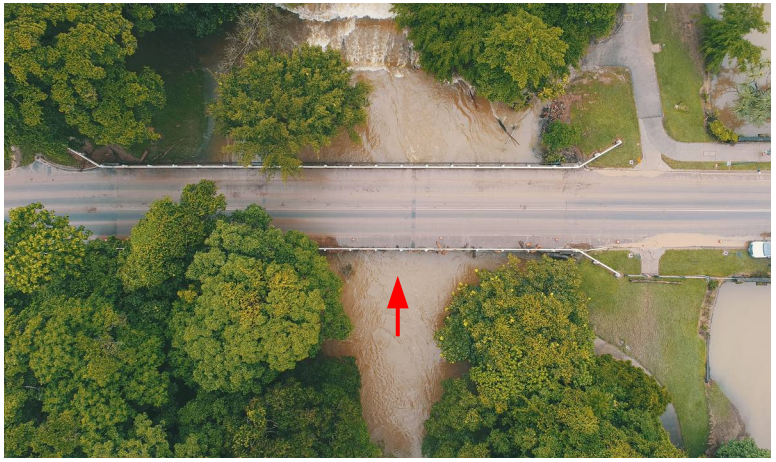
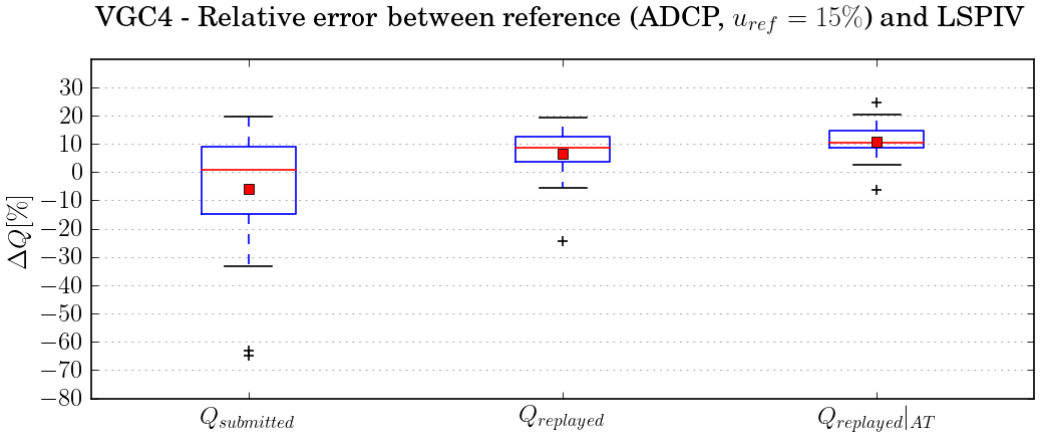
Parameters wizard: Assistance Tools (AT) applied on the VGC2020



Case #4

- Particularities
  - Far distance
  - Hidden parts of the flow (trees)
  - Scaling (no ortho-rectification)



- Dispersion of errors is reduced

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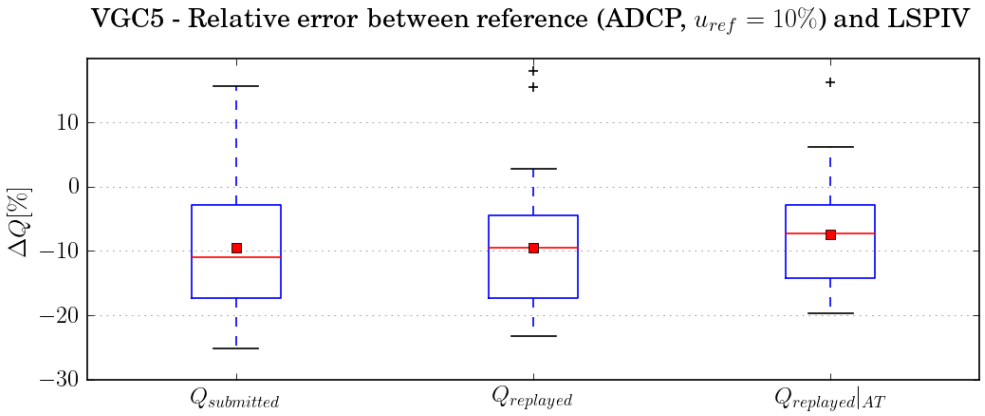
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #5

- Particularities
  - Low tracer density on right side of the flow (shadows)
  - Oblique point of view
  - 2D ortho-rcetification



- Deviations from reference discharge are slightly reduce
- Note: the "grid tricks" was not used. In this case strong errors remain on the right side of the flow due to the lack of tracers

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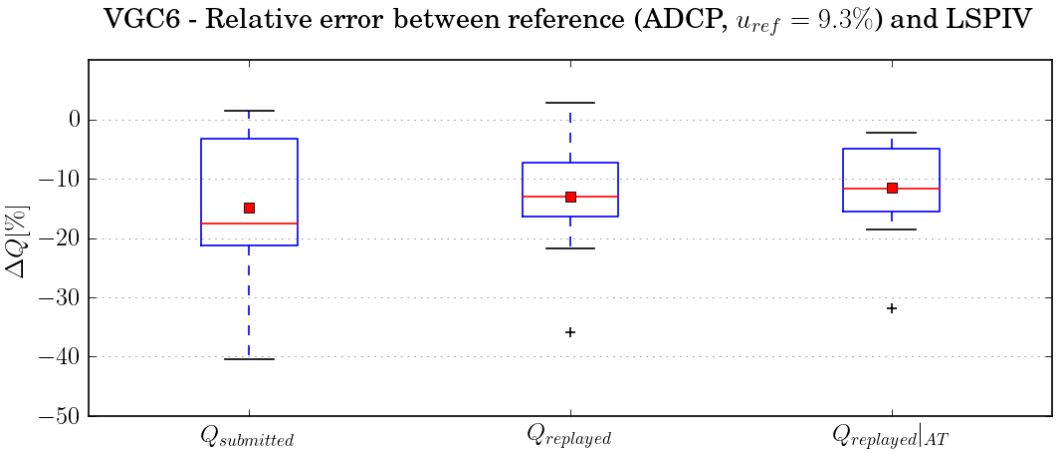
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #6

- Particularities
  - → 3D ortho-rectification



- No amelioration of the results
- In this case, errors were caused by ortho-rectification which explains that assistance tools does not affect the results

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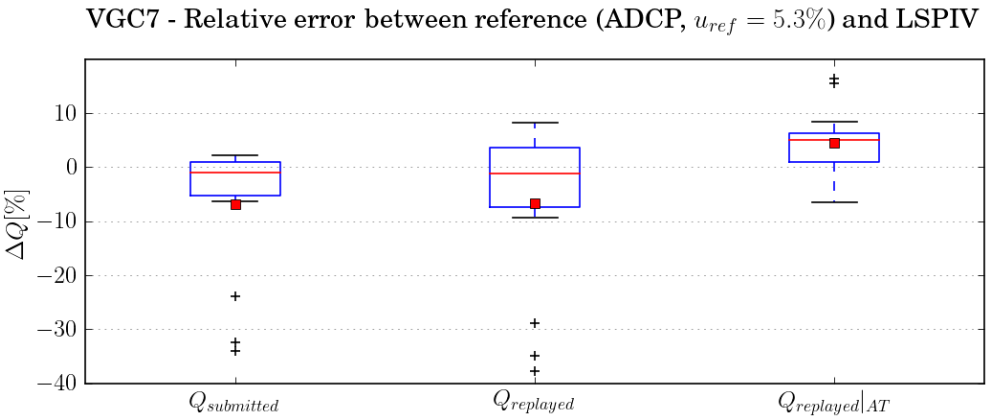
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #7

- Particularities
  - Sun reflections
  - Far distance
    - Low displacements
  - Areas with poor tracers density
  - Scaling (no ortho-rectification)



- Dispersion of the deviations to the reference is slightly reduced
- In this case, the defined grid has a stronger impact on the results. This explains the reduced impact of the assistance tools

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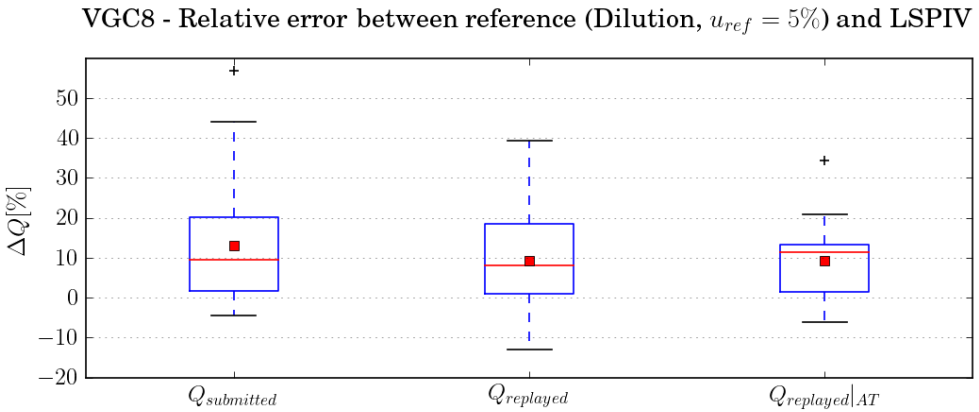
Parameters wizard: Assistance Tools (AT) applied on the VGC2020

Case #8

- Particularities
  - Volatile tracers
  - High displacements
  - Recirculation (rocks on the right side)
  - 2D ortho-rectification



- The assistance tools allowed to **contain errors** with a reduction of higher deviations with reference

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Parameters wizard: Assistance Tools (AT) applied on the VGC2020

- Global amelioration of the results with the assistance tools proposed
- Strong amelioration in the cases without specific error sources (shadows, lack of tracers, ortho-rectification errors, water transparency…)
- Robustness of the LSPIV measurement is enhanced with the assistance tools

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To be continued...

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