



Velocimetría y fluviometría mediante el uso de cámaras fijas y drones

XVI Jornadas de Hidráulica Francisco Javier Domínguez - 17 Noviembre 2022

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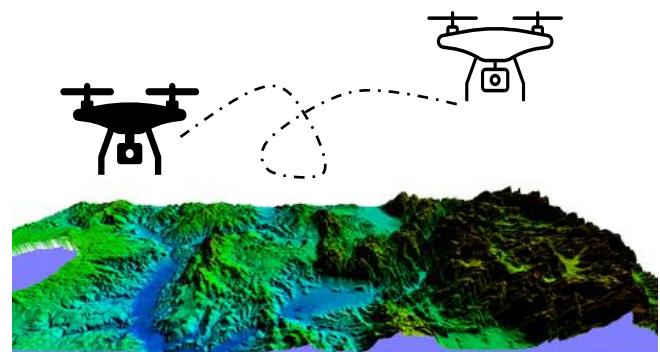
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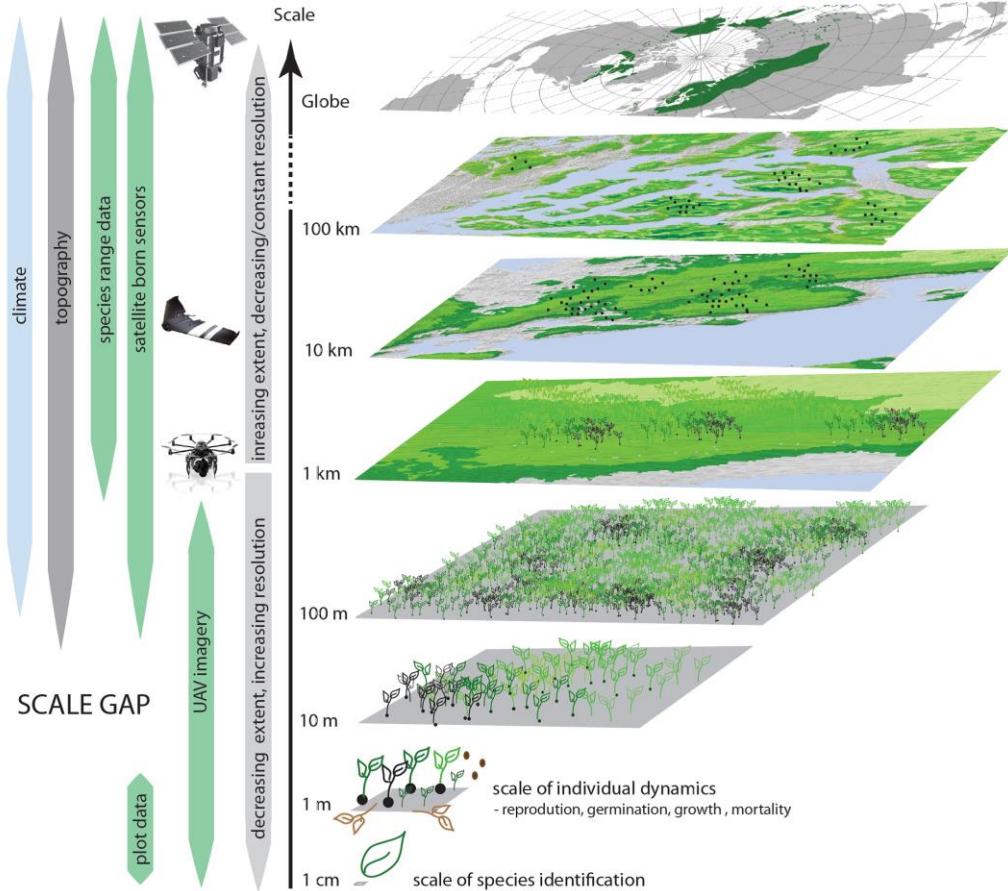
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Monitoreo ambiental en la actualidad

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A qué resolución trabajan distintas metodologías de medición?



Up to
30cm

Up to
1cm

Resolución comparable

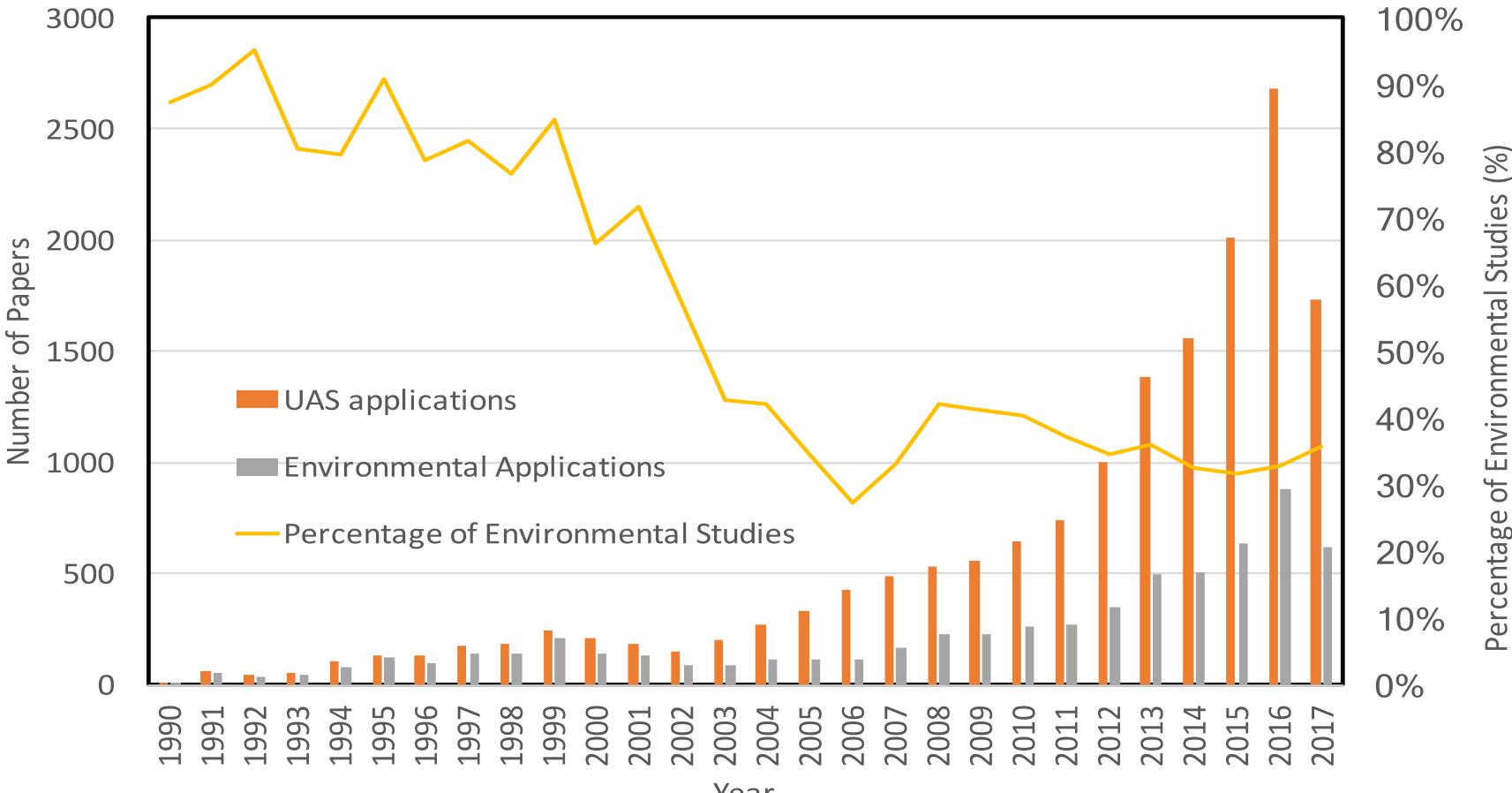
Up to
1cm

Monitoreo ambiental en la actualidad

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Contribuciones científicas

- ✓ Disminución de artículos relacionados con el ambiente
- ✓ Aumento en el uso de UASs
- ✓ Aumento en la resolución



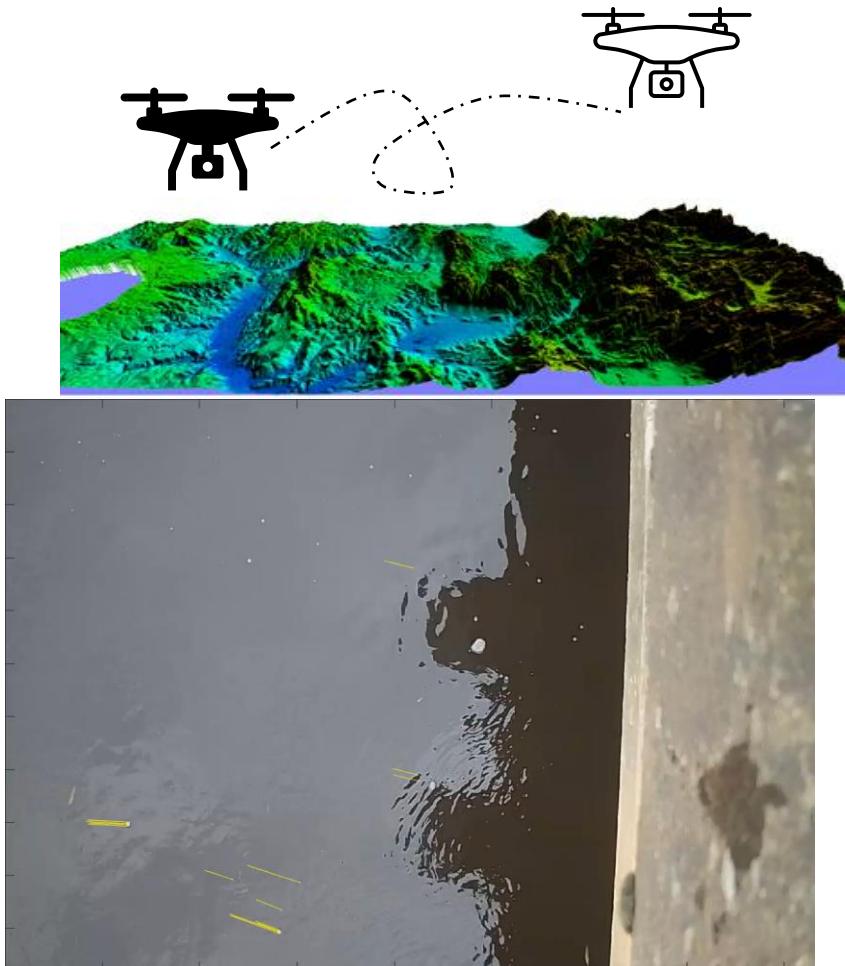
Number of articles extracted from the database ISI-web of knowledge published from 1990 up to 2017 (last access 15 January 2018). Source: Manfreda et al. (2018)

Velocimetría mediante el uso de imágenes

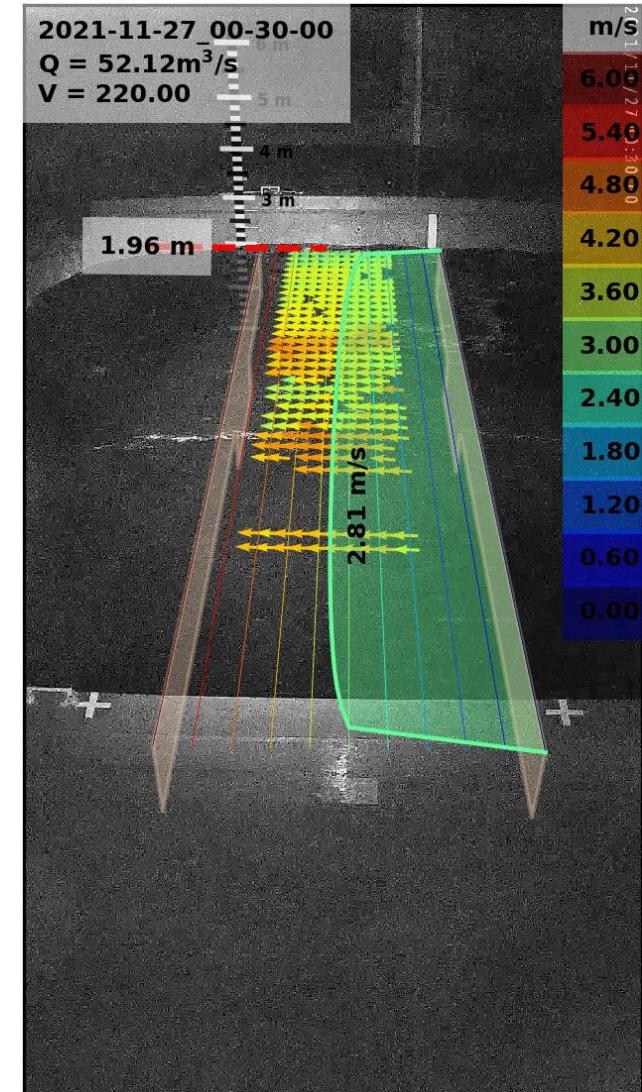
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Ejemplo de aplicación y contexto

- ✓ **Objetivo:** Monitoreo fluvial (velocidades and tirantes hídricos), zonas inundadas, morfología fluvial;
- ✓ **Escala:** Puntual → Cuenca
- ✓ **Métodos:** Velocimetría por imágenes (algunos algoritmos: LSPIV, PTV, STIV);
- ✓ **Versatilidad:** Smartphones, Cámaras fijas, UASs;
- ✓ **Ejemplos de uso operacional:** Suiza, Nueva Zelanda, Australia, entre otros.



River Till, UK. Source: <https://flood-obs.com/river-till-wooler-northumberland/>



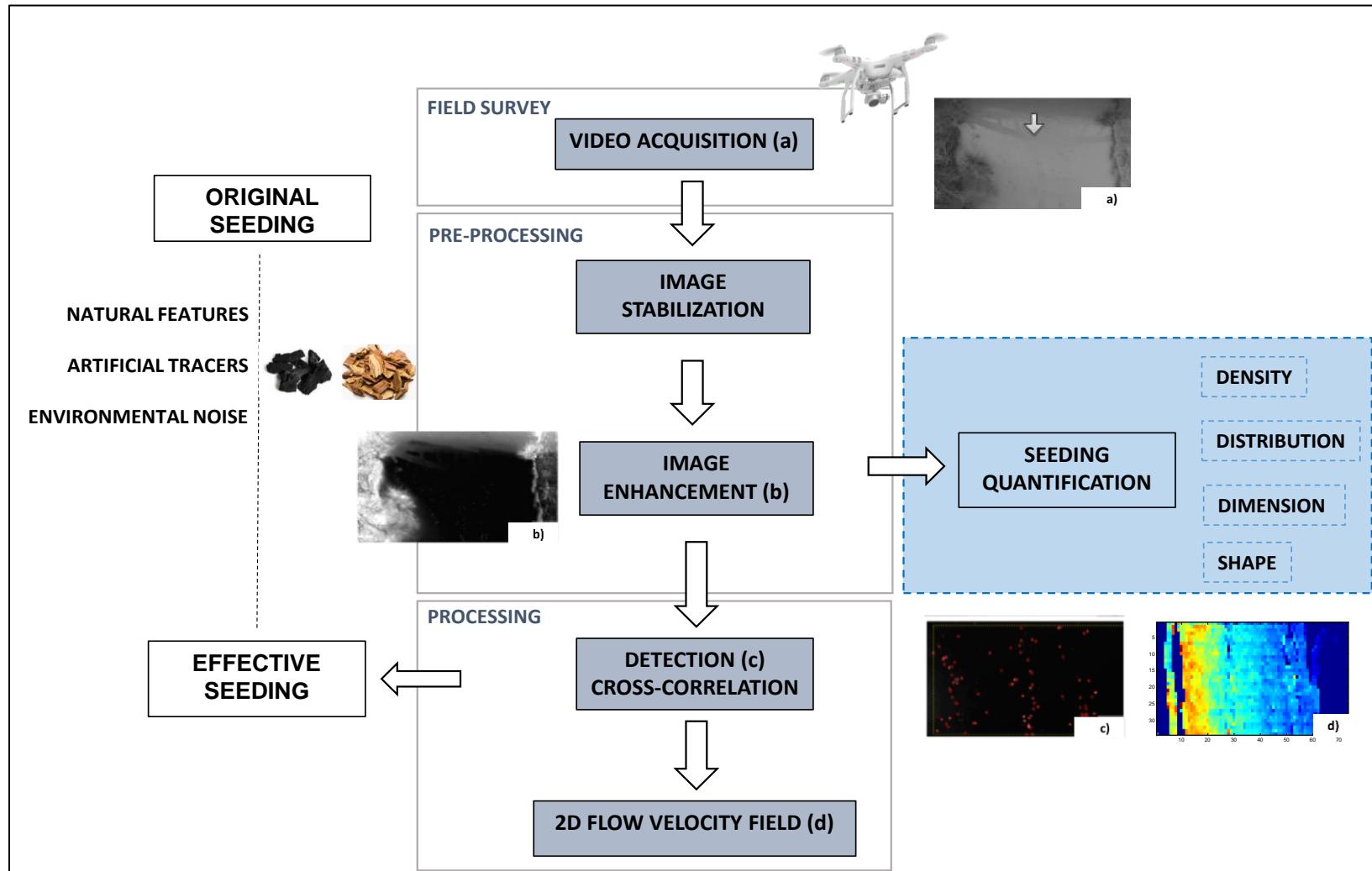
<http://www.photrack.ch/dischargekeep.html>



Velocimetría mediante el uso de imágenes

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Workflow de la velocimetría por imágenes:

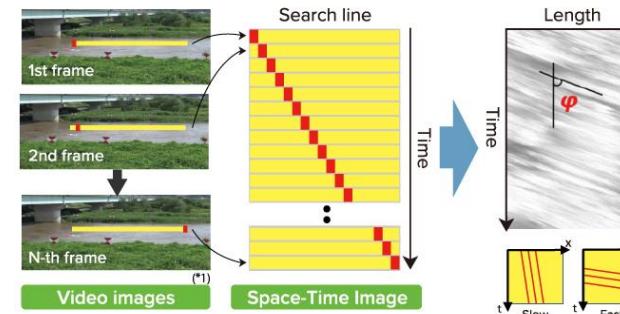
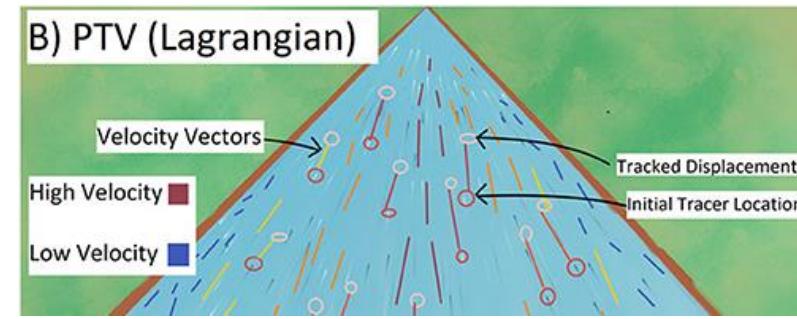
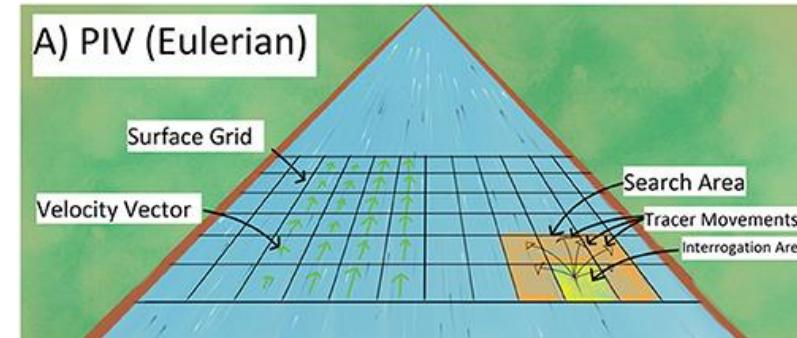


Velocimetría mediante el uso de imágenes

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Algoritmos comúnmente utilizados para el procesamiento

- PARTICLE IMAGE VELOCIMETRY (PIV)
 - USES '**PATTERNS**' OF TRACERS TO DETERMINE DISPLACEMENT
 - INTERROGATION AND SEARCH AREAS DETERMINED BY USER FOR TRACKING
 - OUTPUT IS AN AVERAGE VELOCITY VECTOR FOR EACH 'GRID'
- PARTICLE TRACKING VELOCIMETRY (PTV)
 - DETECTS AND TRACKS **INDIVIDUAL PARTICLES**
 - THE HIGHER THE AMOUNT OF SUCCESSFUL TRACERS, TYPICALLY, THE MORE RELIABLE THE OUTPUT*
 - OUTPUT IS A COLLECTION OF VELOCITY LINES
- SPACE-TIME IMAGE VELOCIMETRY
 - DOES NOT RELY ON TRACERS THE SAME AS PIV AND PTV
 - USES A **CONTRAST IN SURFACE** AND 'TRACER' ALONG A SEARCH LINE
 - HYDRO-STIV IS BECOMING A COMMONLY USED COMMERCIAL PROGRAM



<https://hydrosoke.n.co.jp/en/service/hydrostiv.php>

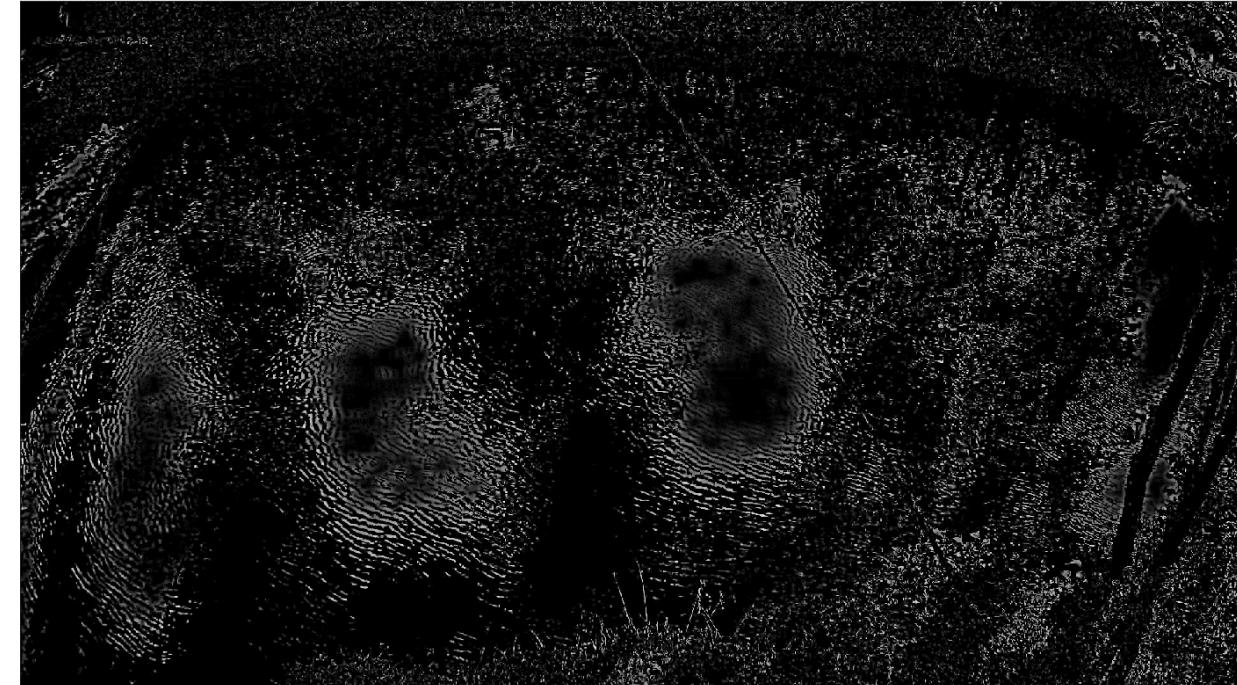
Velocimetría mediante el uso de imágenes

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Ejemplo de aplicación I: Comparación pre & post enhancement



Original

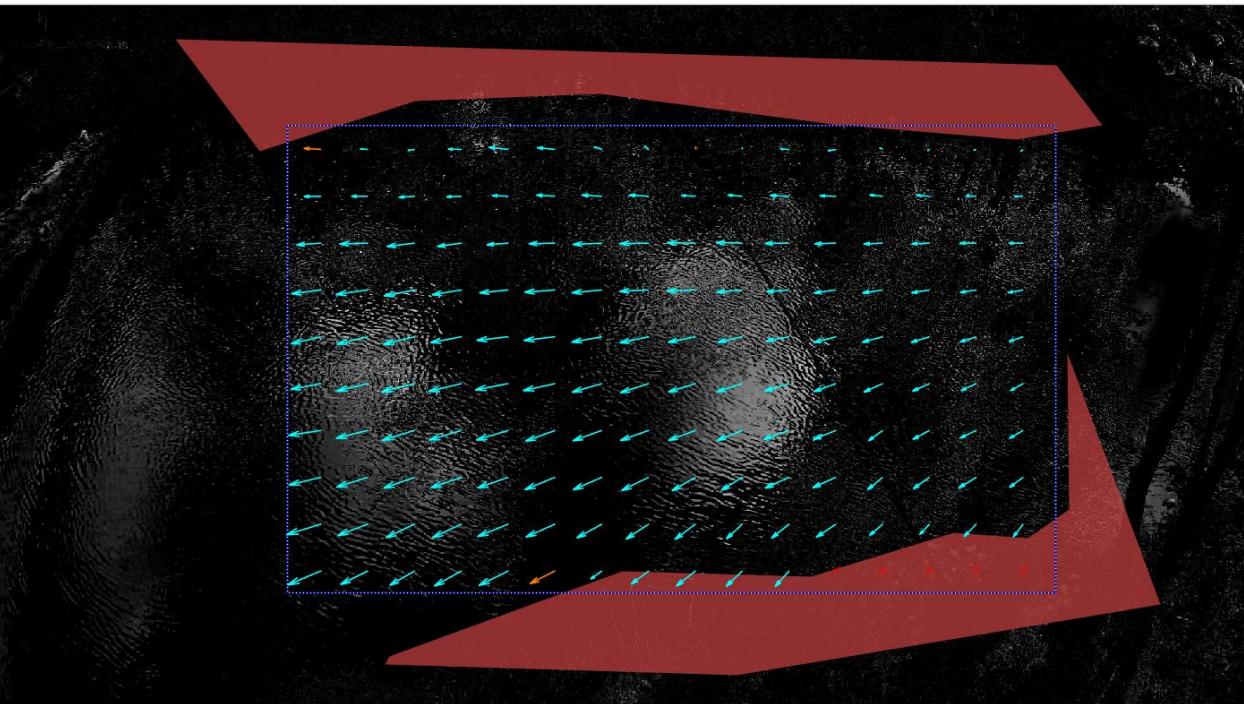


Pre procesado aumentando visibilidad de trazadores

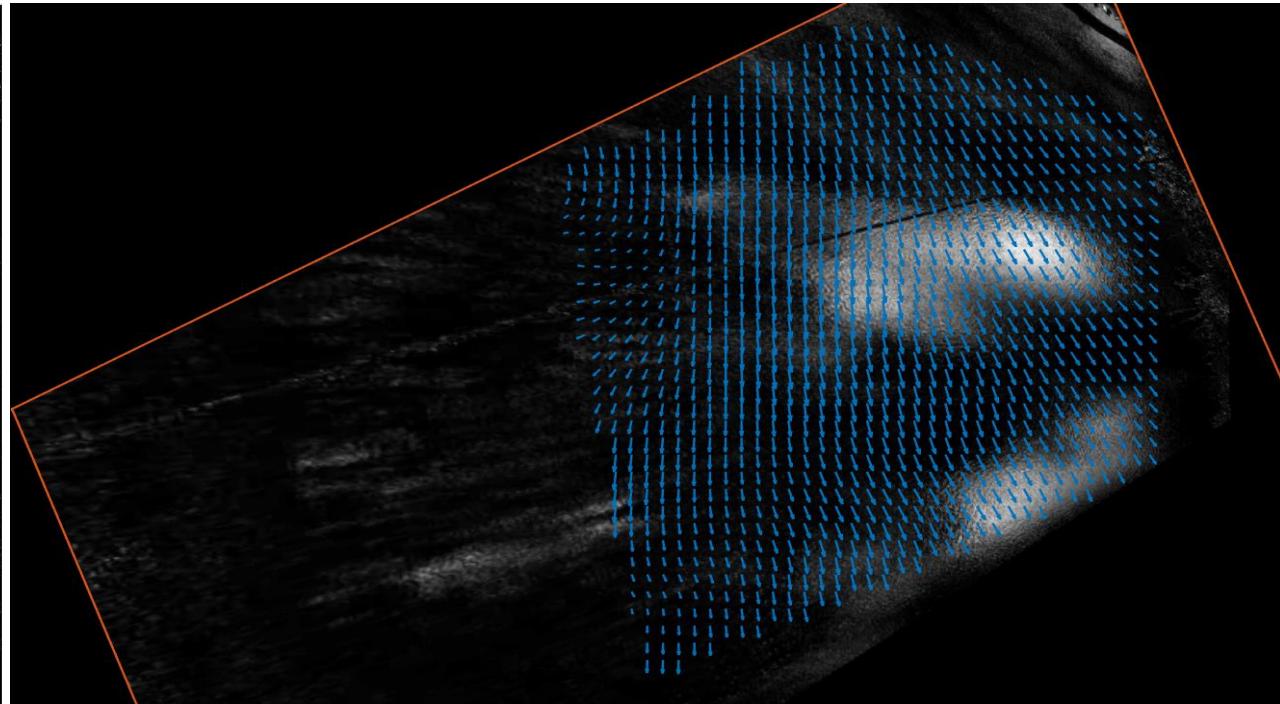
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Ejemplo de aplicación II: Velocidades superficiales & Ortorectificación



Velocidades superficiales

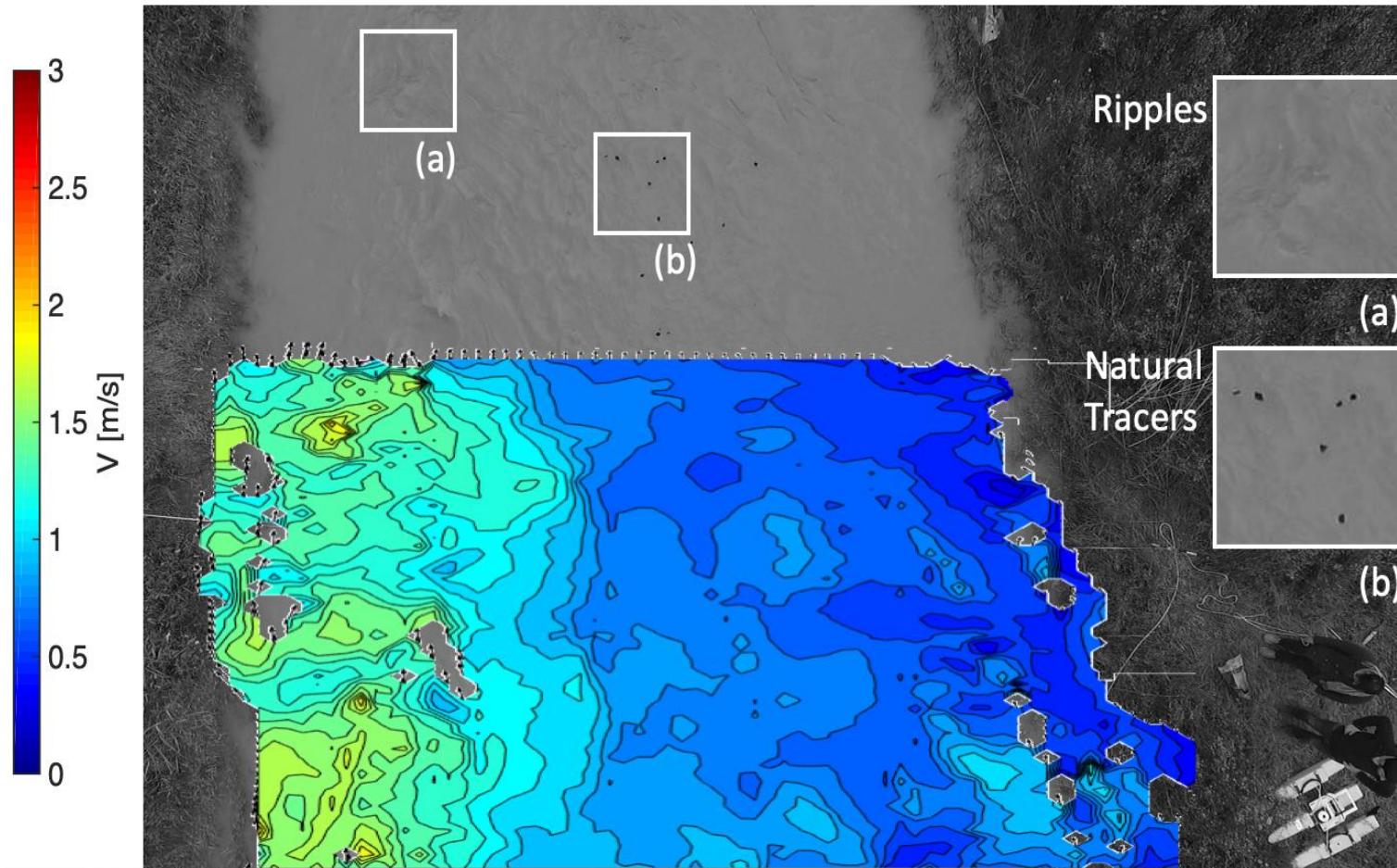


Ortorectificación

Velocimetría mediante el uso de imágenes

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Ejemplo de aplicación III: PTV y campo de velocidad



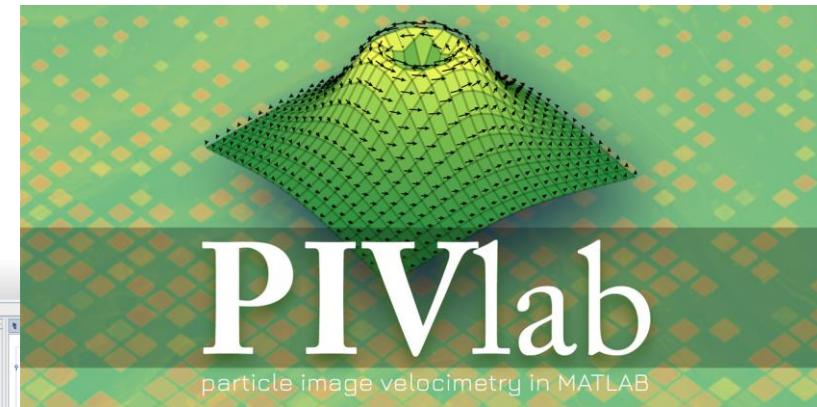
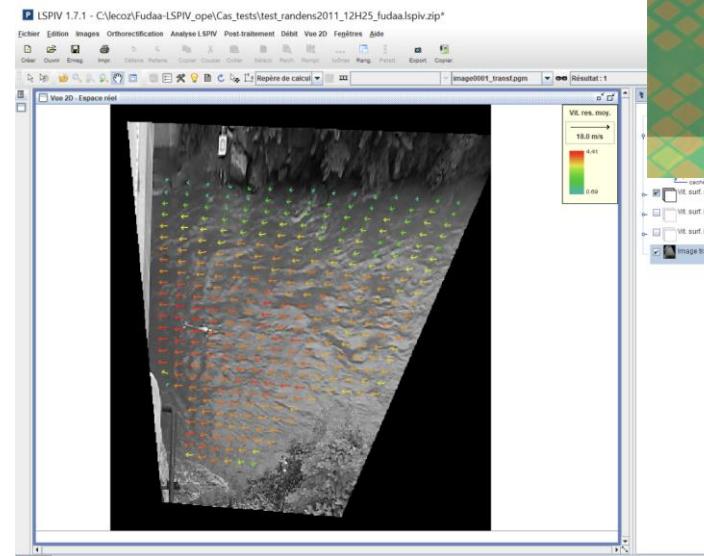
Caso de estudio: Río Bradano, Italia. Video tomado desde un dron

Software disponible para el análisis

10

Particle Image Velocimetry (PIV)

- Several pieces of freely available software
 - Fudaa (Java platform)
 - River (PIVLab, Matlab platform)
- Less sensitive to tracer deformation
 - More of a problem at higher flows
- Relies on particles/tracers flowing through an area
 - Produces an instantaneous velocity vector for that area

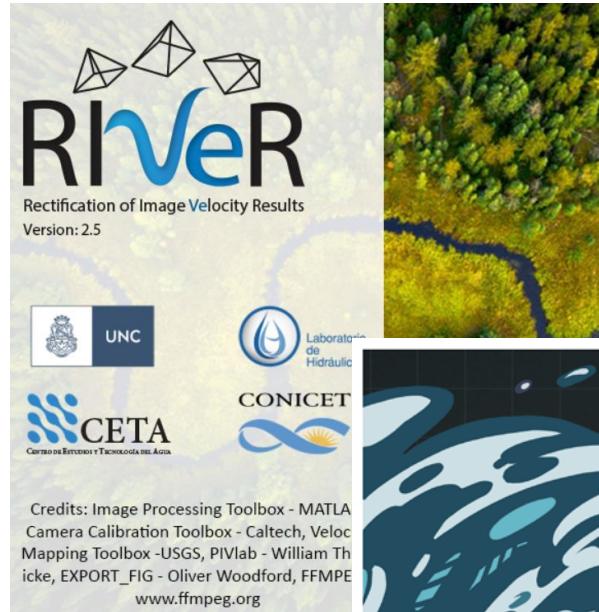


Software disponible para el análisis

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Particle Tracking Velocimetry (PTV)

- Several pieces of freely available software
 - River (PTVLab, Matlab platform)
 - KLT-IV (Matlab platform)
- Relies on stable tracers between interrogation frames
 - Not much of an issue typically at slower flows
- Works well at lower densities
 - Needs a longer video to do so though



Software disponible para el análisis

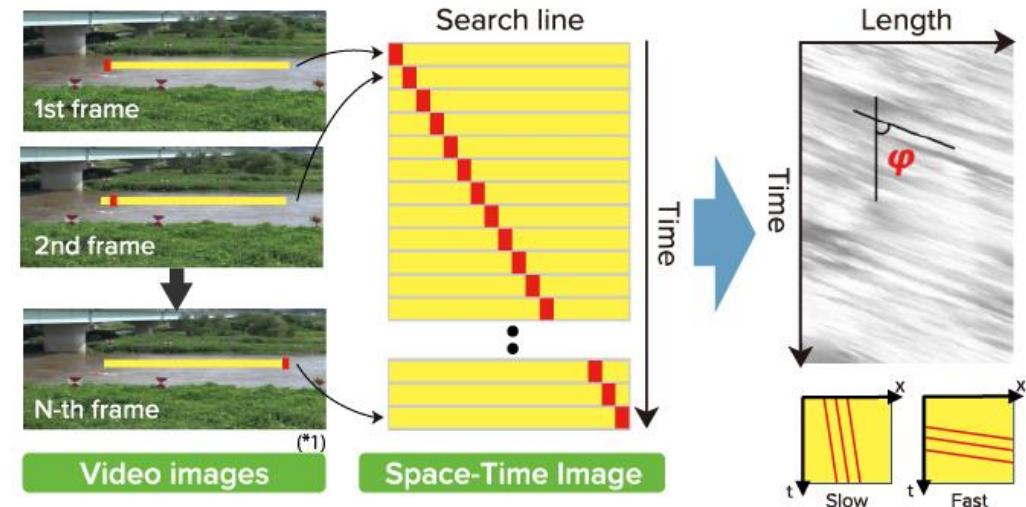
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Space-Time Image Velocimetry (STIV)

- **Hydro-STIV is the main software**
 - Commercial licences available
 - Free trials available from authors
- **One-dimensional flow patterns**
 - PIV and PTV are both 2d surface flows
 - Simplifies data output to surface lines
- **Has been shown to work well at lower flows**
 - Studies in Canada compare hydro-stiv and klt-iv
 - Hydro-stiv was slightly better at lower flows than klt, but klt-iv better at higher flows
- **Uses ‘search lines’ to monitor contrast change**
 - As a tracer or change in contrast goes over a line, its progress along that line is monitored and an angle is associated to its velocity



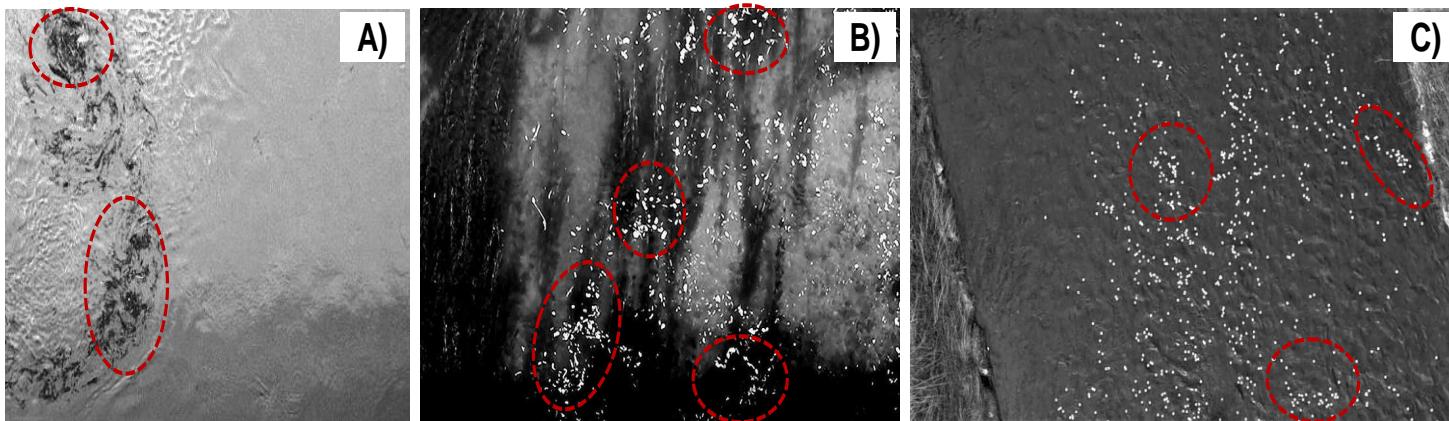
Hydro-STIV



Influencia de los trazadores: Contexto

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Qué pasa en condiciones reales?



A) Trazadores naturales en un evento de crecida en el Río Tíber, Italia (Tauro et al., 2017); B) & C) Trazadores artificiales en el Río Brenta, Italia (Tauro et al., 2017) y Río Murg en Suiza (Detert et al., 2017), respectivamente.

A pesar de que la velocimetría por imágenes se utilice cada día más, la **incertidumbre** de los resultados obtenidos es aún tema de investigación. Entonces, Cómo proceder para optimizar los resultados?



Enfoque NUMÉRICO!

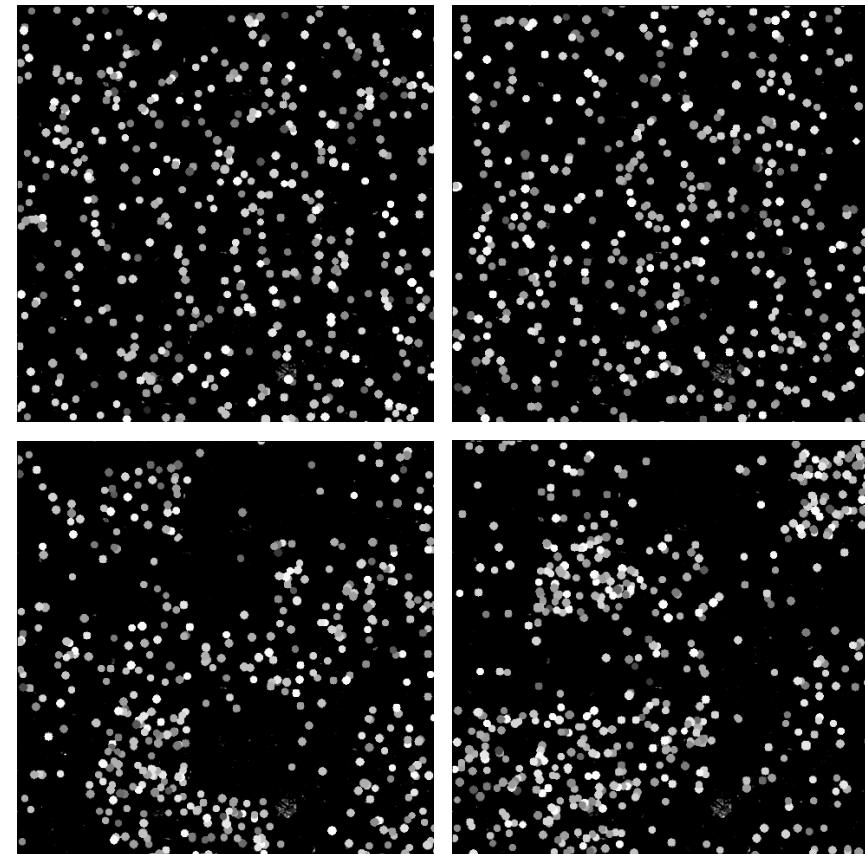
Influencia de los trazadores: Simulación Numérica

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Generación sintética de trazadores:

- Trazadores sintéticos distribuidos en el espacio con velocidad unidireccional y constante (15 px/frame);
- Forma? Circular con un diámetro $D_{xp} \approx 10$ px y color en escala de grises;
- La distribución espacial fue generada siguiendo la distribución Generalizada de Poisson con una densidad λ y un nivel de agregación v ;
- Los errores fueron determinados usando la siguiente Ec.:

$$\epsilon = 100 \times \frac{(u_c - u_R)}{u_R}$$

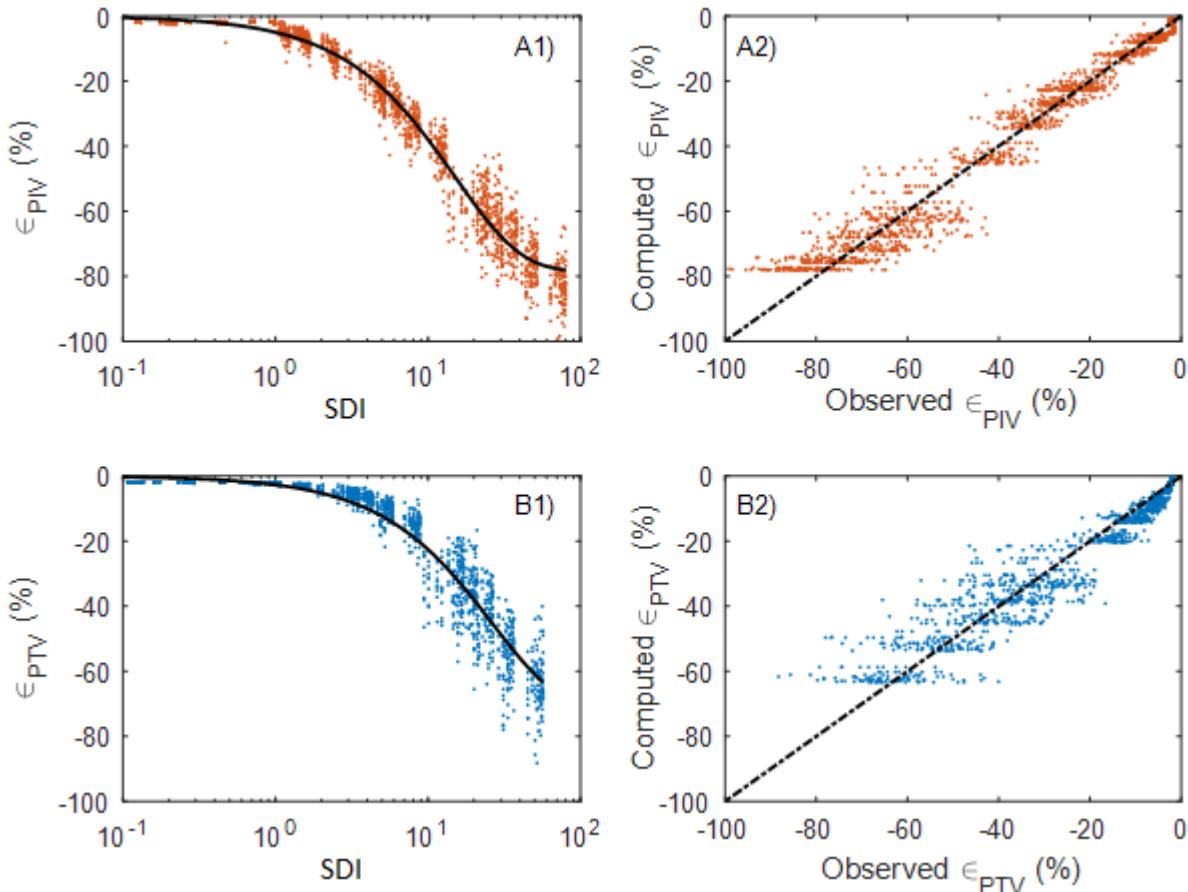


Simulaciones numéricas de trazadores sintéticamente generados con distintos niveles de agregación: en total **33,600** imágenes

Influencia de los trazadores: El adimensional SDI

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Análisis dimensional y SDI:



Numerical simulations of synthetically generated particles that present different aggregation levels.

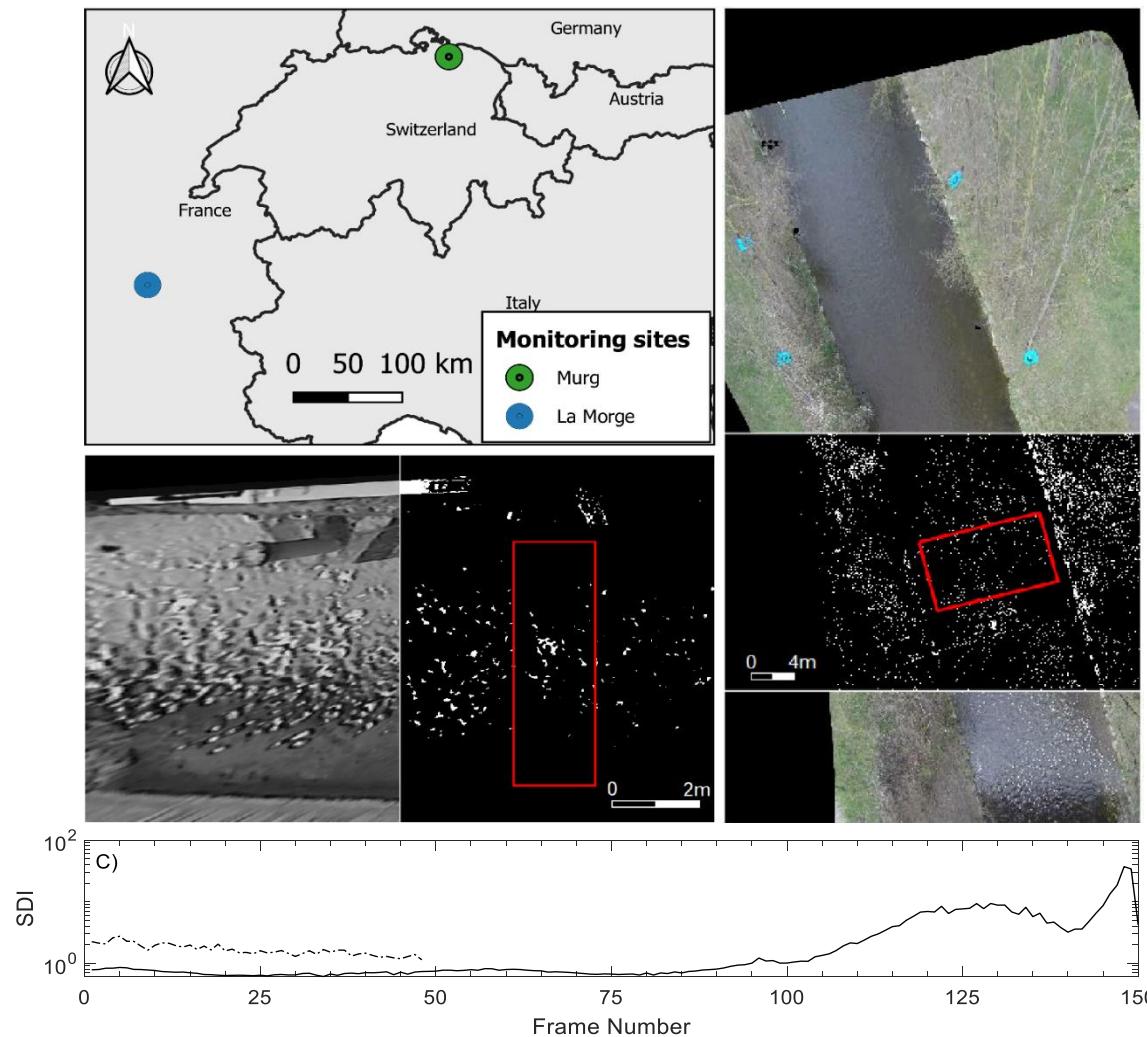
$$SDI = D^{*0.1} / \left(\frac{\rho}{\rho_c D^{*1}} \right)$$

- ✓ ρ := Seeding density
- ✓ D^* := Dispersion Index
- ✓ Clearly visible relationship between Errors and SDI.
- ✓ The lower SDI, the lower the Errors.

Influencia de los trazadores: Ejemplo de aplicación

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SDI applications: 1.0



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SCIENTIFIC BRIEFING



Refining image-velocimetry performances for streamflow monitoring: Seeding metrics to errors minimization

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Abstract

River streamflow monitoring is currently facing a transformation due to the emerging of new innovative technologies. Fixed and mobile measuring systems are capable of quantifying surface flow velocities and discharges, relying on video acquisitions. This camera-gauging framework is sensitive to what the camera can "observe" but also to field circumstances such as challenging weather conditions, river background transparency, transiting seeding characteristics, among others. This short communication paper introduces the novel idea of optimizing image velocimetry techniques selecting the most informative sequence of frames within the available video. The selection of the optimal frame window is based on two reasonable criteria: (a) the maximization of the number of frames, subject to (b) the minimization of the recently introduced dimensionless seeding distribution index (SDI). SDI combines seeding characteristics such as seeding density and spatial clustering of tracers, which are used as a proxy to enhance the reliability of image velocimetry techniques. Two field case studies were considered as a proof-of-concept of the proposed framework, on which seeding metrics were estimated and averaged in time to select the proper application window. The selected frames were analysed using LSPIV to estimate the surface flow velocities and river discharge. Results highlighted that the proposed framework might lead to a significant error reduction. In particular, the computed discharge errors, at the optimal portion of the footage, were about 0.40% and 0.12% for each case study, respectively. These values were lower than those obtained, considering all frames available.

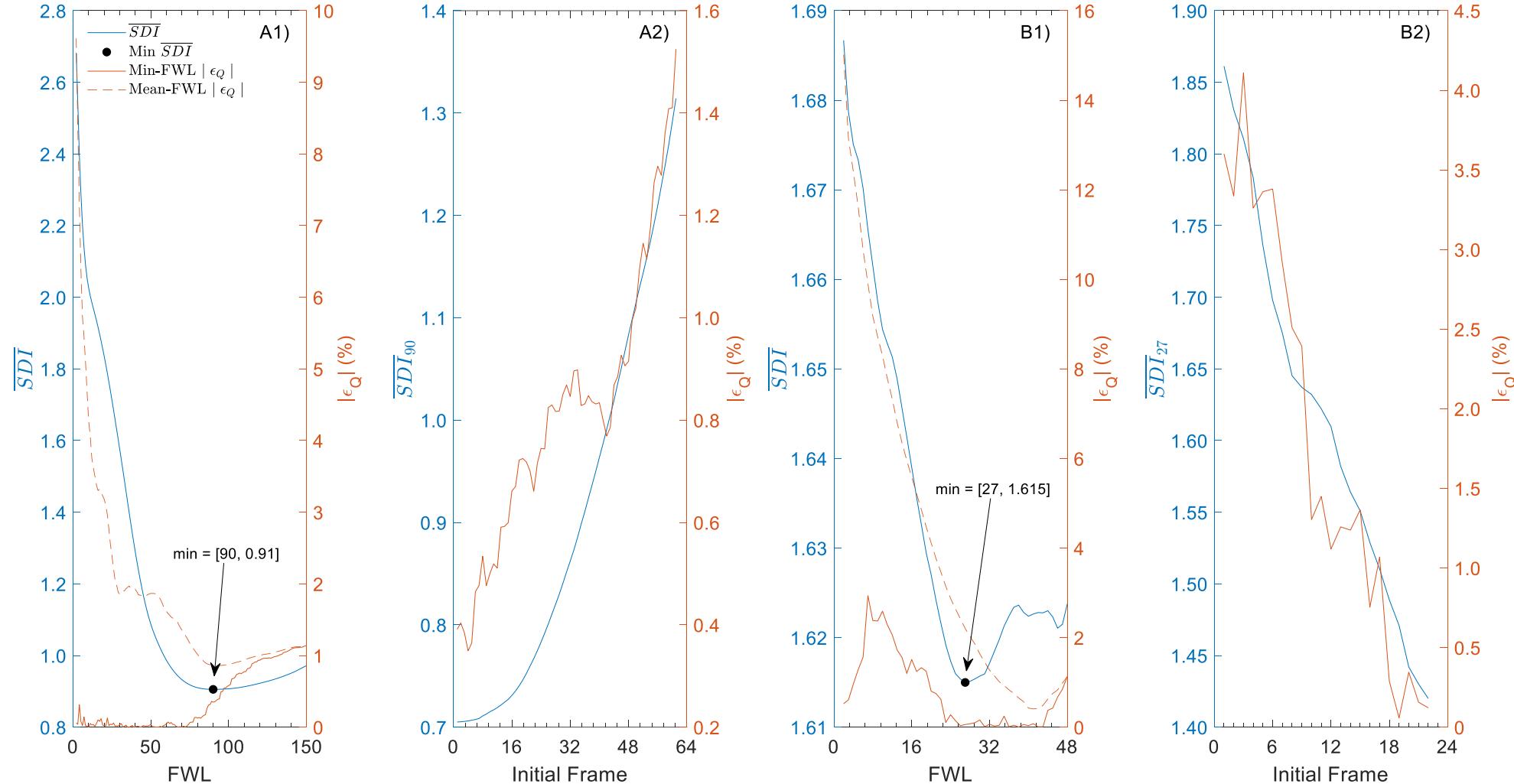
KEYWORDS
discharge, fluvial monitoring, hydrometry, large-scale particle image velocimetry, optimization,



Influencia de los trazadores: Ejemplo de aplicación

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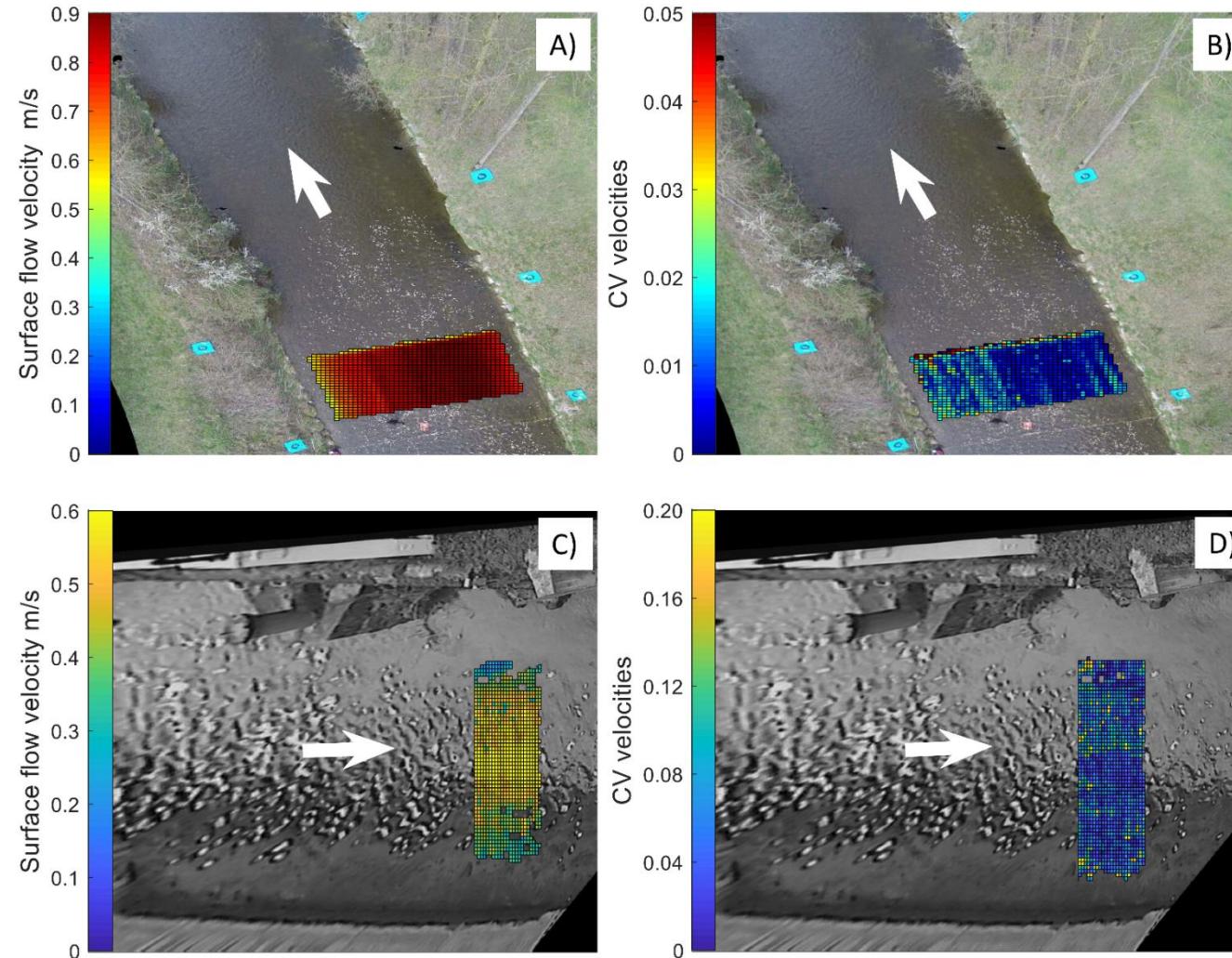
SDI applications: 1.0



Influencia de los trazadores: Ejemplo de aplicación

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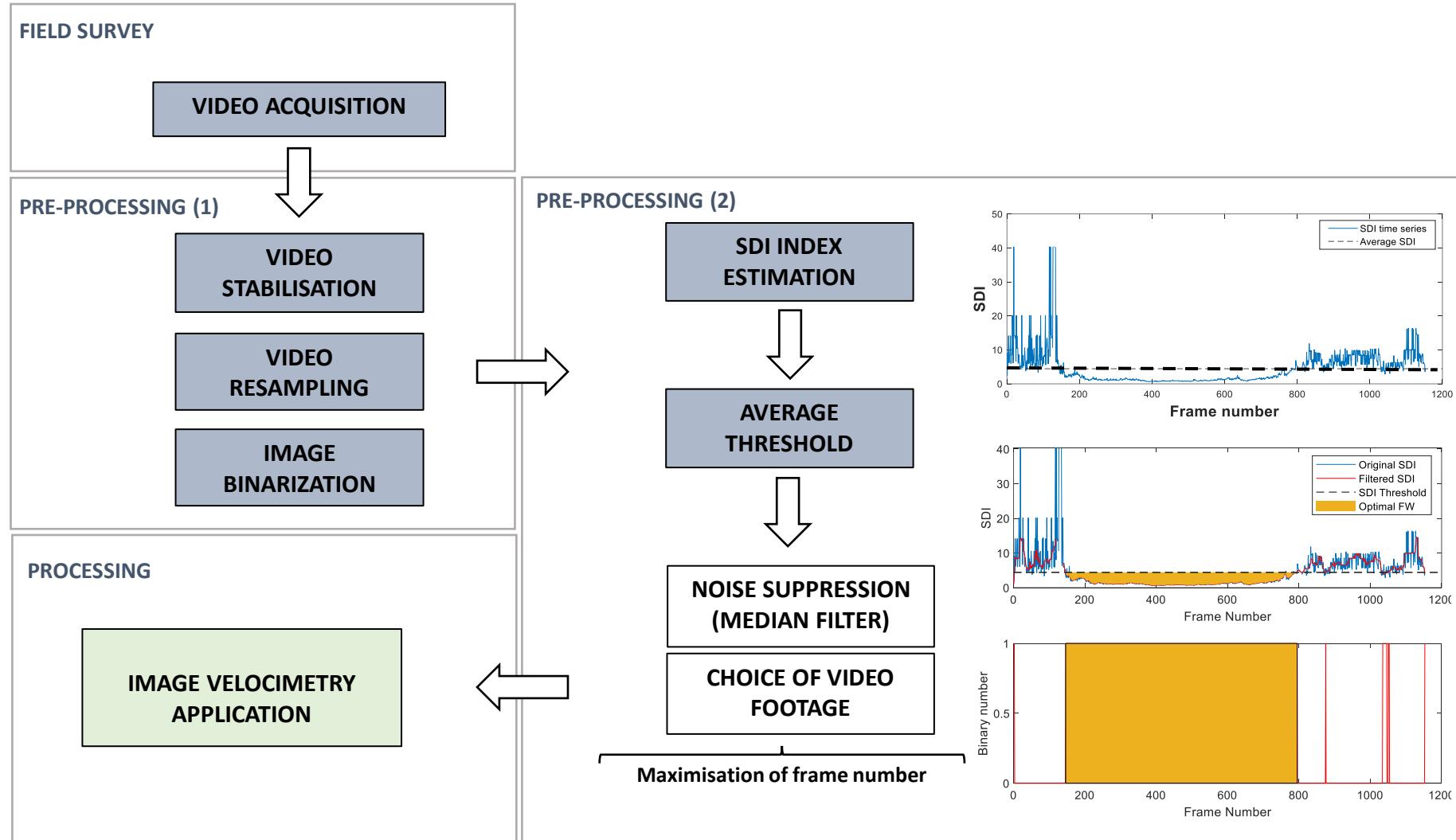
SDI applications: 1.0



Influencia de los trazadores: Ejemplo de aplicación

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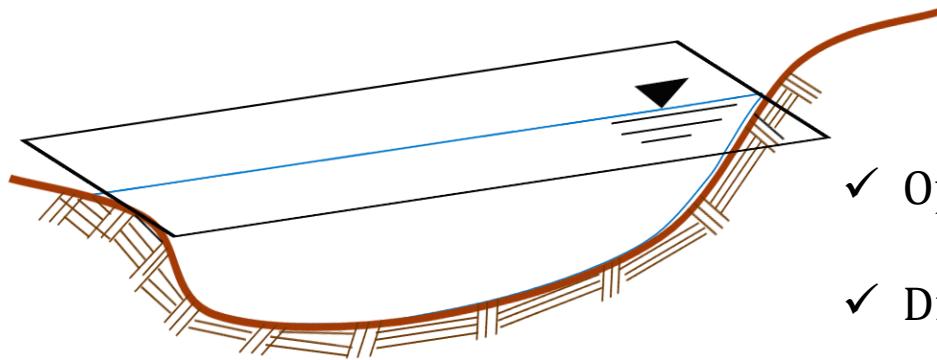
SDI applications: 2.0



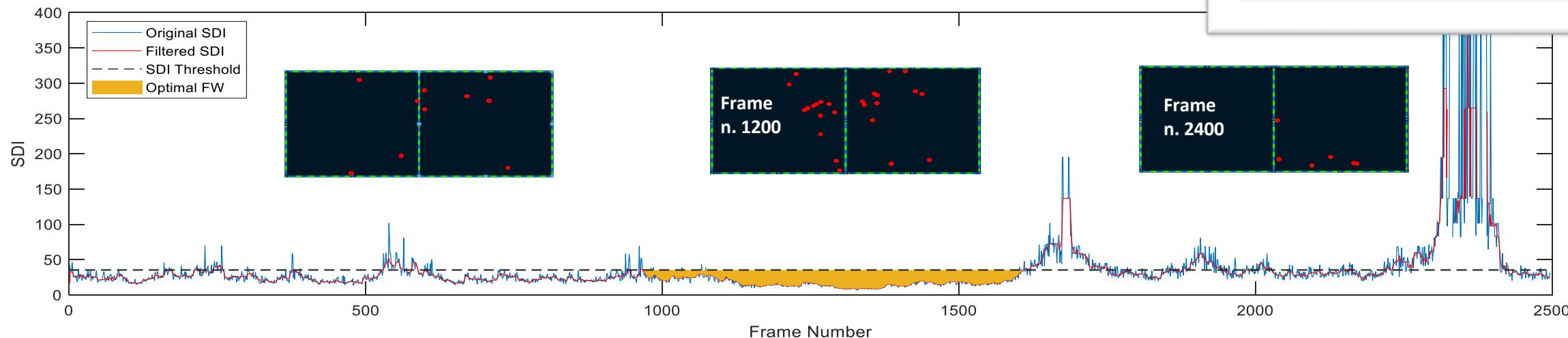
Influencia de los trazadores: Ejemplo de aplicación

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SDI applications: 2.0



- ✓ Optimal FW approach based on SDI.
- ✓ Different spatial scales.
- ✓ Errors reduction of ~20-40 %



Journal of Hydrology
Available online 8 May 2021, 126438
In Press, Journal Pre-proof



Research papers

Increasing LSPIV performances by exploiting the seeding distribution index at different spatial scales

Silvano Fortunato Dal Sasso ^a, Alonso Pizarro ^b, Sophie Pearce ^c, Ian Maddock ^c, Salvatore Manfreda ^b

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Highlights

- A new method based on the seeding distribution index to increase LSPIV performances in natural environments.
- Application of the method at different spatial scales for the identification of the optimal frame window to analyse.
- Identification of a seeding-density-calibrated threshold to ease the analysis in rivers.



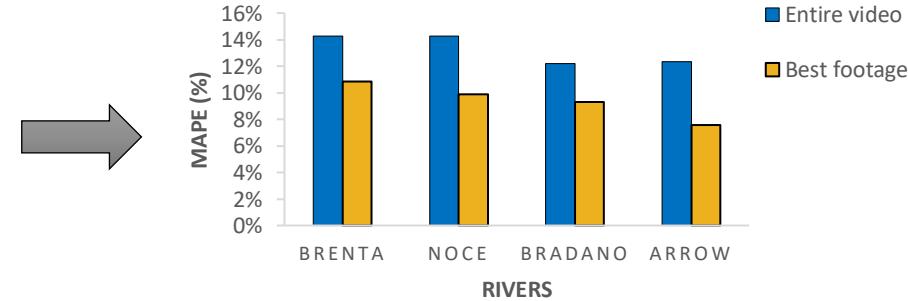
Influencia de los trazadores: Ejemplo de aplicación

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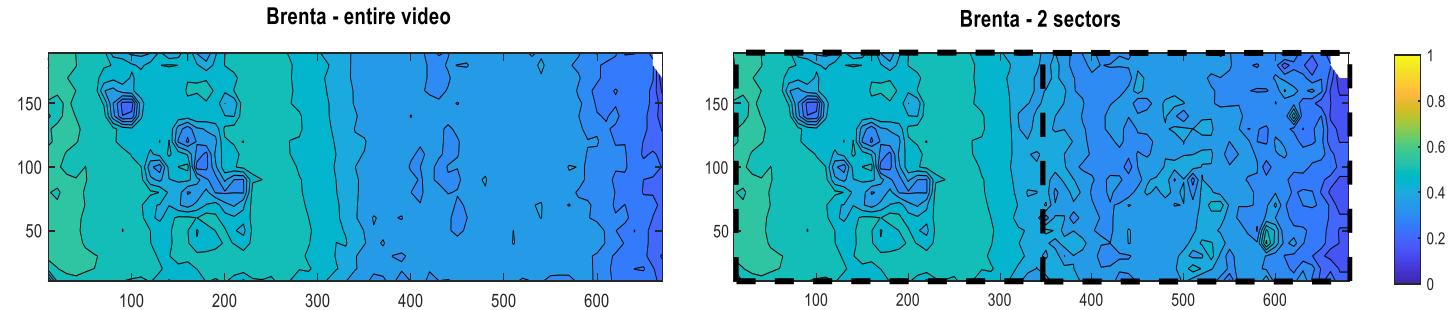
SDI applications: 2.0

- The SDI-based method improved LSPIV performances with a reduction of image velocimetry errors at sector and sub-sector scales

River	Number of frames	
	Entire video	Best footage
Brenta	2500	153
Noce	200	70
Bradano	2496	642
Arrow	799	282



- In such cases, the average surface velocity maps contain details (e.g., velocity fluctuations and divergences) that are not visible and appreciable in the entire video configuration (standard approach).



Conclusiones

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- ✓ A priori evaluation of flow seeding conditions can allow choosing the **best frame window** for image velocimetry analysis;
- ✓ We observed an **error reduction** of 20-39% with respect to the analysis of the full video (standard case). This beneficial effect appears even more evident when the optimisation is applied at sub-sector scales, in cases where SDI shows a marked variability along the cross-section;
- ✓ The application of the method at the sector and sub-sector scales allowed a significant reduction in computational time for the analysis, reducing the number of frames processed; i.e. **OPTIMISATION**;
- ✓ The method appears suitable for **natural settings** where environmental and hydraulic conditions are extremely challenging and particularly useful for **real-time implementations on gauge cams**, where a vast number of frames is usually recorded and analysed.
- ✓ In future, this method will be tested on other case studies considering additional seeding configurations and environmental conditions.



Códigos y Disponibilidad de datos

23

- **Pizarro, A.**, Dal Sasso, S. F., & Manfreda, S. (2022). *VISION: VIdeo StabilisatION using automatic features selection*. <https://doi.org/10.17605/OSF.IO/HBRF2>
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- **Pizarro, A.**, Dal Sasso, S. F., Perks, M. T., & Manfreda, S. (2020). *Identifying the optimal spatial distribution of tracers for optical sensing of stream surface flow*. <https://doi.org/10.17605/OSF.IO/8EGQW>



Referencias y Lectura recomendada

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- Dal Sasso, **Pizarro, A.** et al. (2021) “Increasing LSPIV performances by exploiting the seeding distribution index at different spatial scales”. Journal of Hydrology, 598, 126438. <https://doi.org/10.1016/j.jhydrol.2021.126438>
- **Pizarro, A.** et al. (2020) “Identifying the optimal spatial distribution of tracers for optical sensing of stream surface flow”. Hydrology and Earth System Sciences (HESS), <https://doi.org/10.5194/hess-24-5173-202015>.
- **Pizarro, A.**, Dal Sasso, S. F., Manfreda, S.(2020)“Refining image-velocimetry performances for streamflow monitoring: Seeding metrics to errors minimisation”. Hydrological Processes; 1–9. <https://doi.org/10.1002/hyp.1391916>.
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- Perks, M., **Pizarro, A.** et al. (2020)“Towards harmonisation of image velocimetry techniques for river surface velocity observations”.Earth Syst. Sci. Data, 12, 1545–1559, <https://doi.org/10.5194/essd-12-1545-2020>





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