



# The achievements HARMONIOUS COST Action

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Professor of Hydrology and Advanced Monitoring - [www.salvatoremanfreda.it](http://www.salvatoremanfreda.it)

**HARMONIOUS TEAM:** Salvatore Manfreda, Brigitta Toth, David Helman, Giorgos Mallinis, Richard Lucas, Pauline Miller, Antonino Maltese, Petr Dvořák, Sander Múcher, Giuseppe Ciralo, Yijian Zeng, Zhongbo Su, Jana Müllerová, Nunzio Romano, Xurxo Gago, Ruodan Zhuang, Goran Tmusic, Helge Aasen, Mike James, Gil Concalves, Eyal Ben-Dor, Anna Brook, Maria Polinova, Jose Juan Arranz, Janos Meszaros, Ruodan Zhuang, Kasper Johansen, Yoann Malbeteau, Matthew McCabe, Isabel Pedroso de Lima, Corine Davis, Sorin Herban, Sophie Pearce, Robert Ljubicic, Salvador Peña-Haro, Matthew Perks, Flavia Tauro, Alonso Pizarro, Silvano Fortunato Dal Sasso, Dariia Strelnikova, Salvatore Grimaldi, Ian Maddock, Gernot Paulus, Jasna Plavšic, Dušan Prodanovic, Rafi Kent, Josef Brůna, Martynas Bučas, Joan Estrany, Adrien Michez, Martin Mokroš, Maria Tsiafouli, João L. M. P. de Lima, László Bertalan

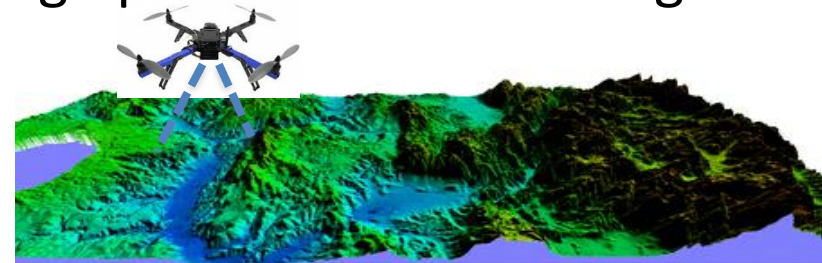
# Unmanned Aerial Systems (UAS) for Environmental Monitoring

**Scope:** improve ability to monitor river basin processes

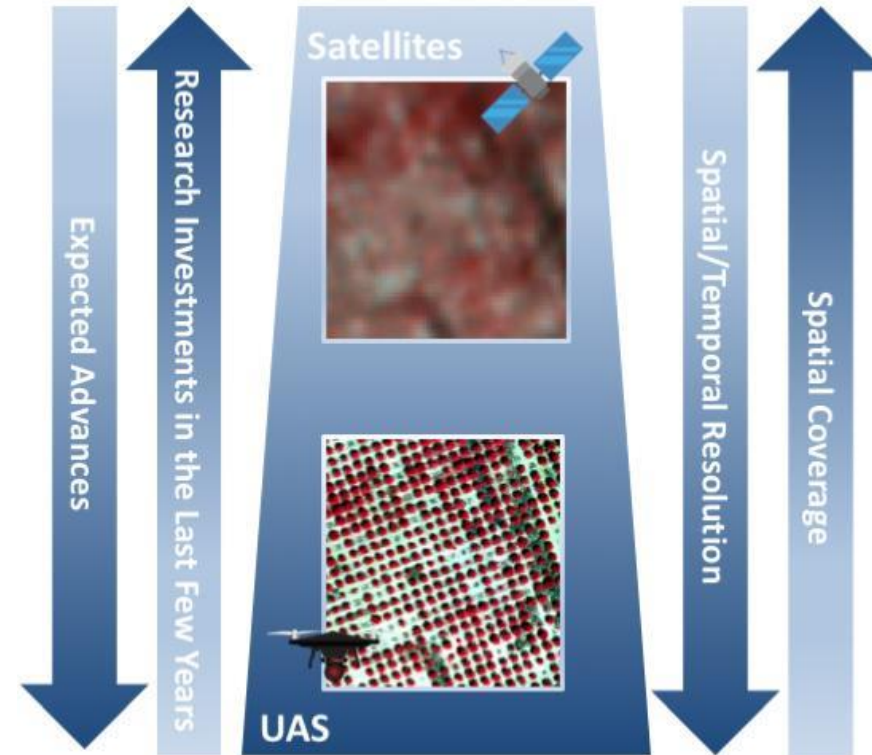
**Variable of interests:** state of the vegetation, soil water content, streamflow (flow velocity and water level), flooded areas and river morphology.

**Objective:** define integrated procedures to improve hydrological/hydraulic monitoring capacity using UAS.

**Scale:** from plot-scale to the river basin scale providing operational monitoring tools.



# UAS vs Satellite

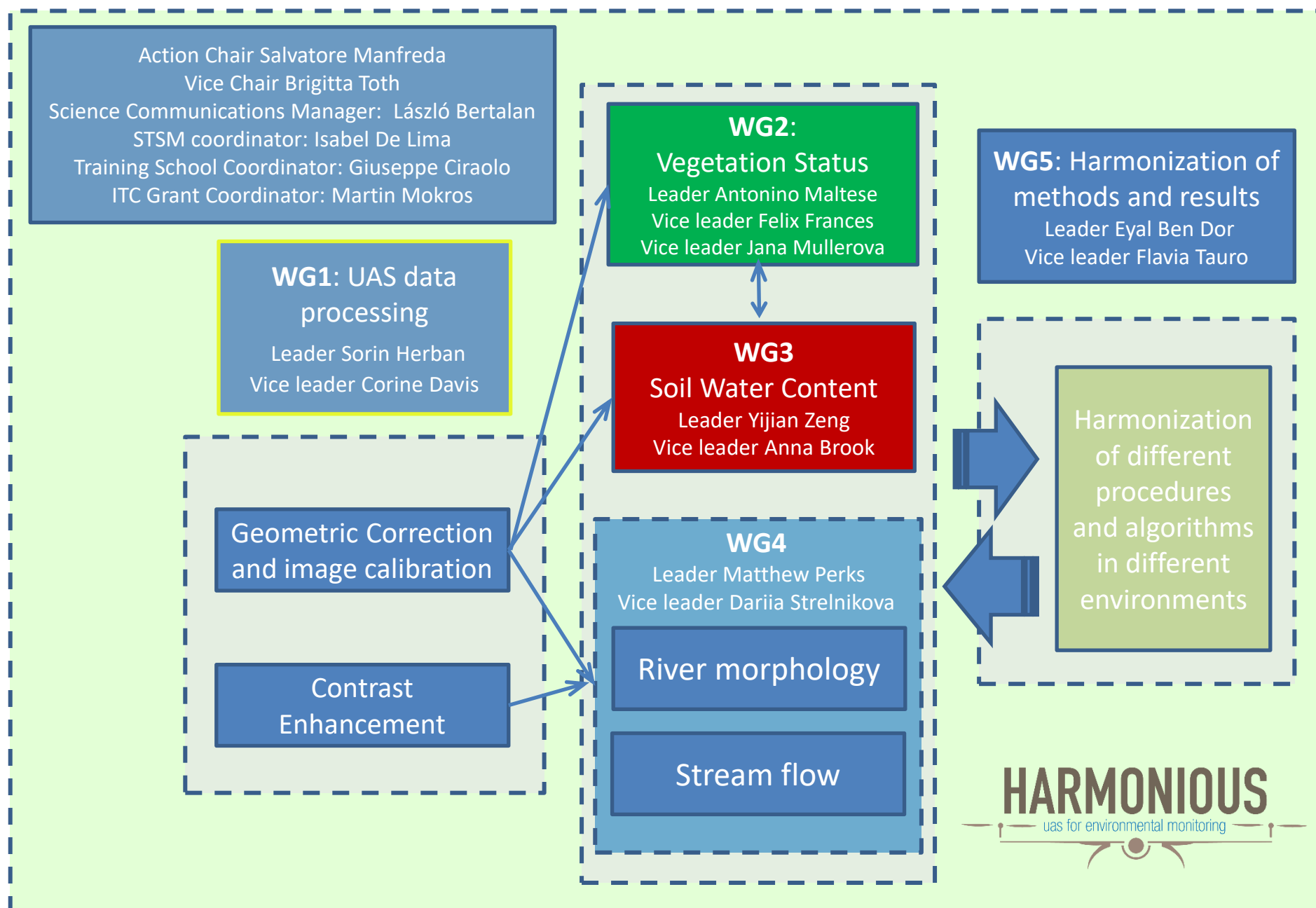


([Manfreda et al., Remote Sensing 2018](#))

## CA16219 - COST Action HARMONIOUS

- A network of scientists is currently cooperating within the framework of a COST (European Cooperation in Science and Technology) Action named “Harmonious”.
- **The aim of “Harmonious” is to promote monitoring strategies, establish harmonized monitoring practices, and transfer most recent advances on UAS methodologies to others within a global network.**
- HARMONIOUS involves 36 Countries





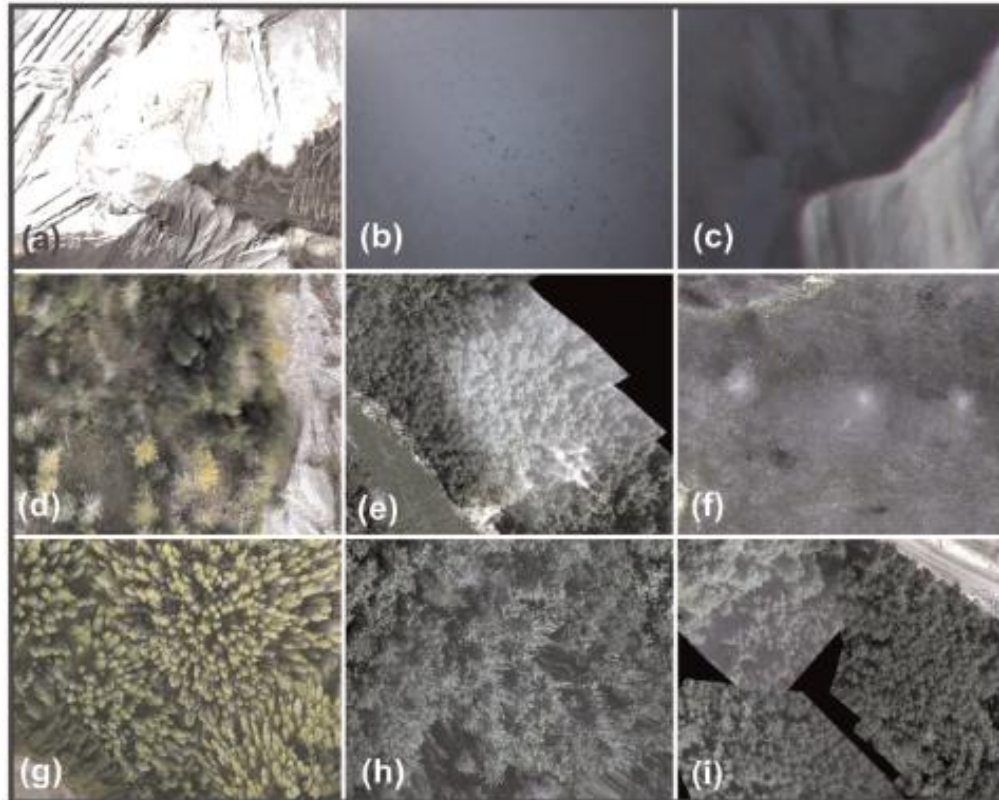
# Stay Connected with Us



CUBO  
AMARILLO  
SALA

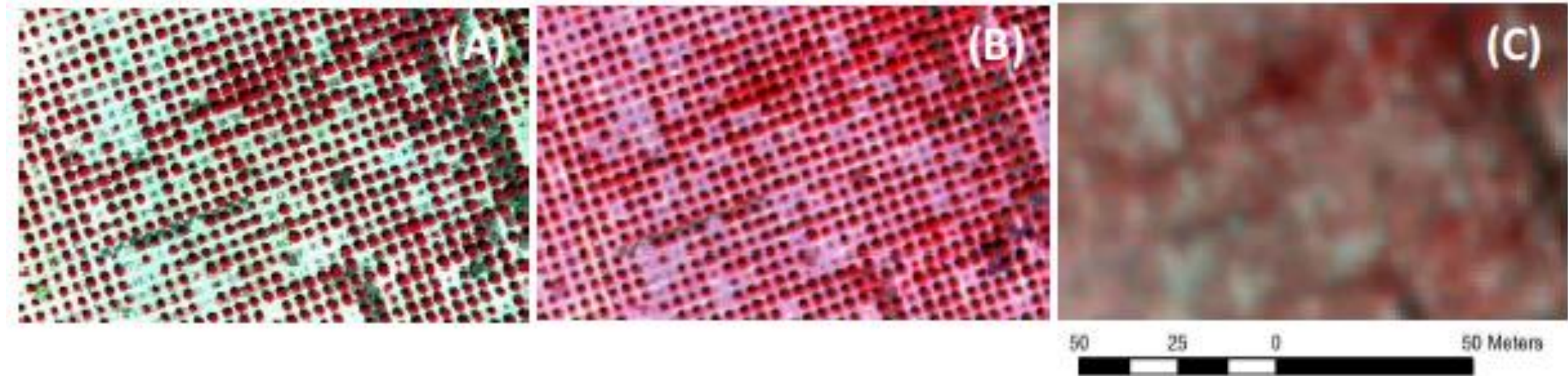


## Examples of Common Image Artifacts



- a) saturated image;
- b) vignetting;
- c) chromatic aberration;
- d) mosaic blurring in overlap area;
- e) incorrect colour balancing;
- f) hotspots on mosaic due to bidirectional reflectance effects;
- g) relief displacement (tree lean) effects in final image mosaic;
- h) Image distortion due to DSM errors;
- i) mosaic gaps caused by incorrect orthorectification or missing images.

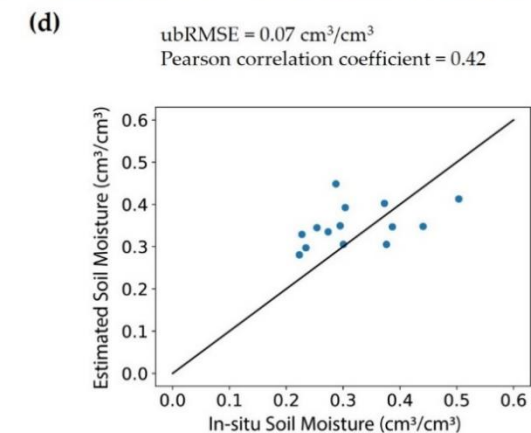
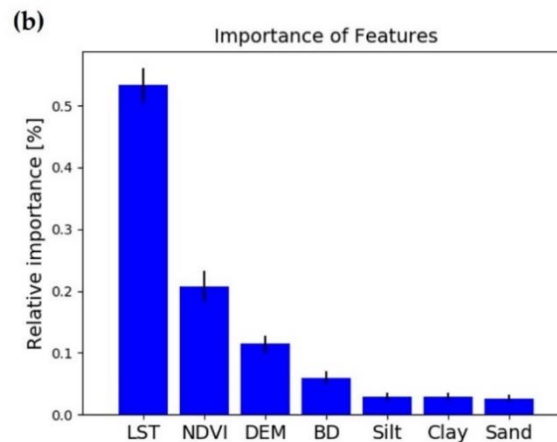
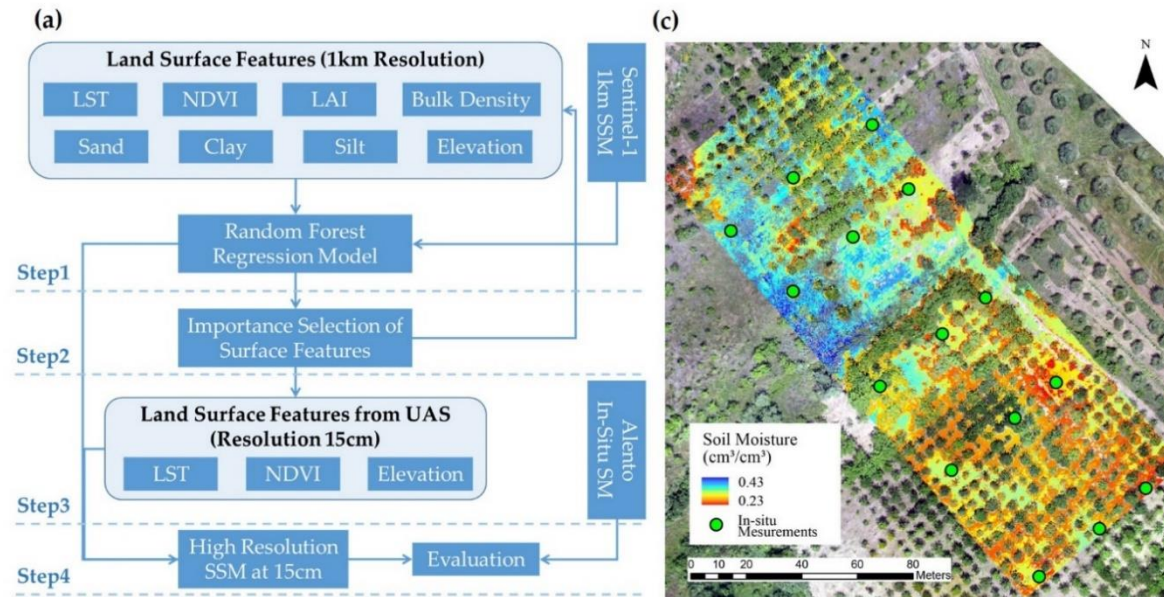
## Comparison between a Satellite, CubeSat and UAS NDVI map



Multi-spectral false colour (near infrared, red, green) imagery collected over the RoBo Alsahba date palm farm near Al Kharj, Saudi Arabia. Imagery (from L-R) shows the resolution differences between: (A) UAV mounted Parrot Sequoia sensor at 50 m height (0.05 m); (B) a WorldView-3 image (1.24 m); and (C) Planet CubeSat data (approx. 3 m).

# Soil Water Content Monitoring

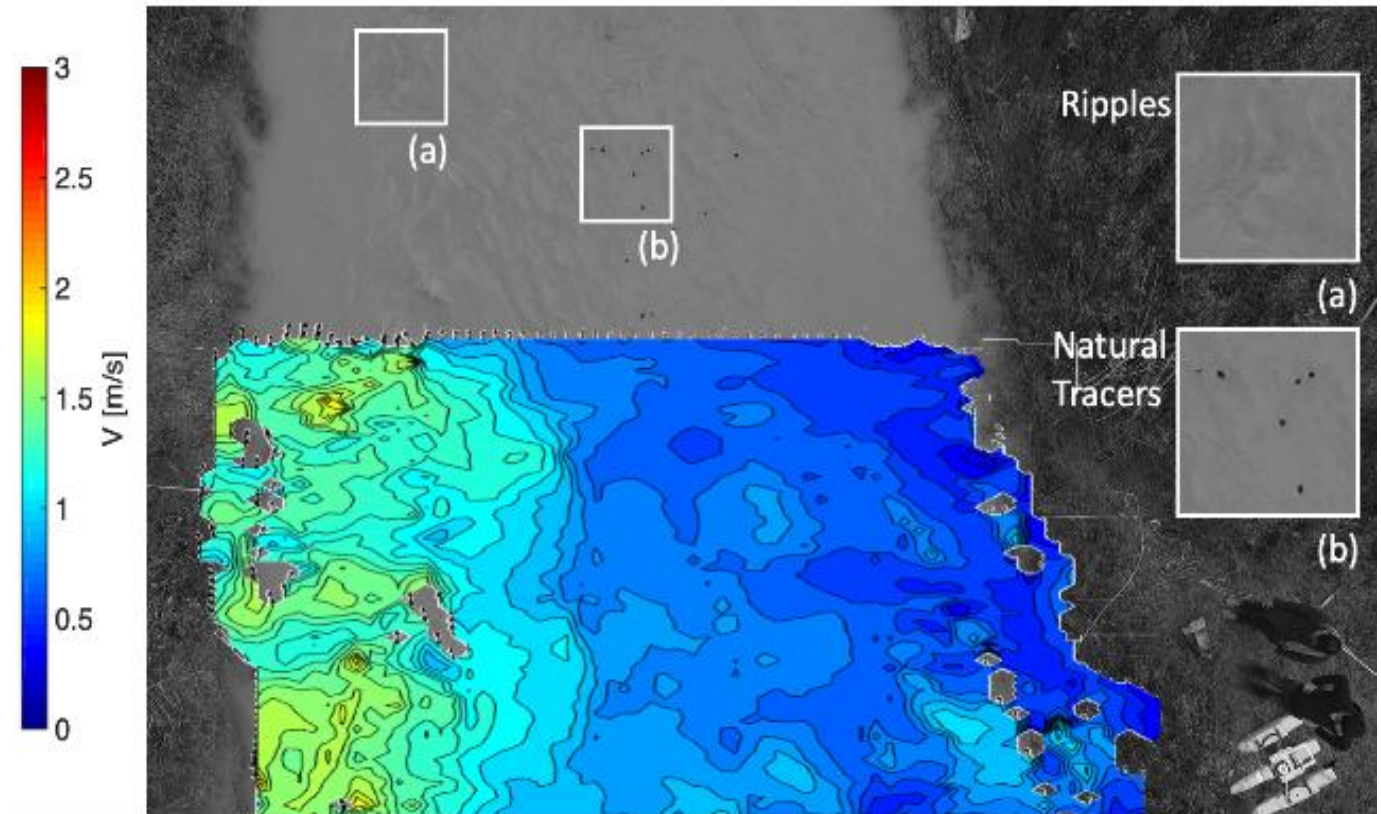
- a) Soil moisture downscaling workflow based on random forest regression (RF);
- b) The importance of land surface features for the RF model;
- c) RF-based soil moisture products at 15cm;
- d) Comparison of the downscaled soil moisture with in-situ measurements.



(Su et al., Water 2020)

## Image Velocimetry

2-D flow velocity field derived using an optical camera mounted on a quadcopter hovering over a portion of the Bradano river system in southern Italy. One of the images used for the analysis is shown as a background, where surface features used by flow tracking algorithms are highlighted in the insets (a, b).



# Stream Flow Monitoring – Data Collection for Benchmarking Optical Techniques

<https://doi.org/10.5194/essd-2019-133>  
Preprint. Discussion started: 26 September 2019  
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Open Access  
Earth System  
Science  
Data  
Discussions

## Towards harmonization of image velocimetry techniques for river surface velocity observations

Matthew T. Perks<sup>1</sup>, Silvano Fortunato Dal Sasso<sup>2</sup>, Alexandre Hauet<sup>3</sup>, Jérôme Le Coz<sup>4</sup>, Sophie Pearce<sup>5</sup>, Salvador Peña-Haro<sup>6</sup>, Flavia Tauro<sup>7</sup>, Salvatore Grimaldi<sup>7, 8</sup>, Borbála Hortobágyi<sup>1</sup>, Magali Jodeau<sup>9, 10</sup>, Ian Maddock<sup>5</sup>, Lionel Pénard<sup>4</sup>, and Salvatore Manfreda<sup>2</sup>

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<sup>4</sup>Irstea, UR RiverLy, River Hydraulics, Villeurbanne, France

<sup>5</sup>School of Science and the Environment, University of Worcester, Worcester, UK.

<sup>6</sup>Photrack AG: Flow Measurements, Ankerstrasse 16a, 8004 Zürich, Switzerland

<sup>7</sup>Department for Innovation in Biological, Agro-food and Forest Systems, University of Tuscia, Viterbo, Italy

<sup>8</sup>Department of Mechanical and Aerospace Engineering, Tandon School of Engineering, New York University, Brooklyn, NY, United States.

<sup>9</sup>Electricité de France, R&D, Chatou, France

<sup>10</sup>LHSV, Chatou, France

Correspondence: Matthew T. Perks ([matthew.perks@ncl.ac.uk](mailto:matthew.perks@ncl.ac.uk))

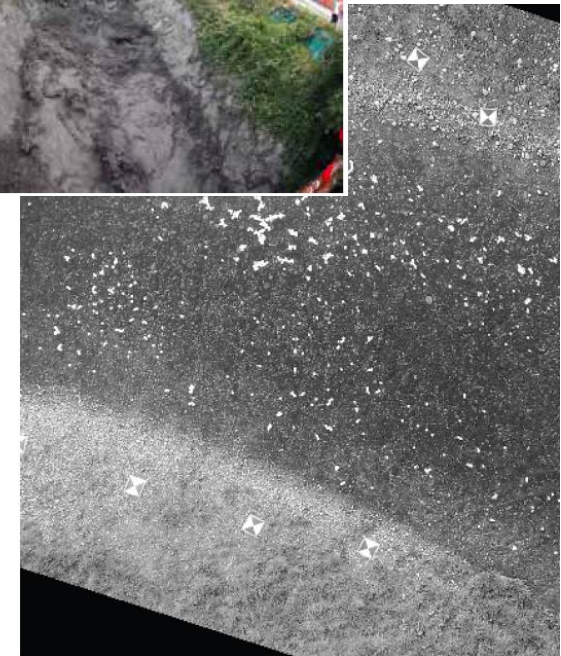
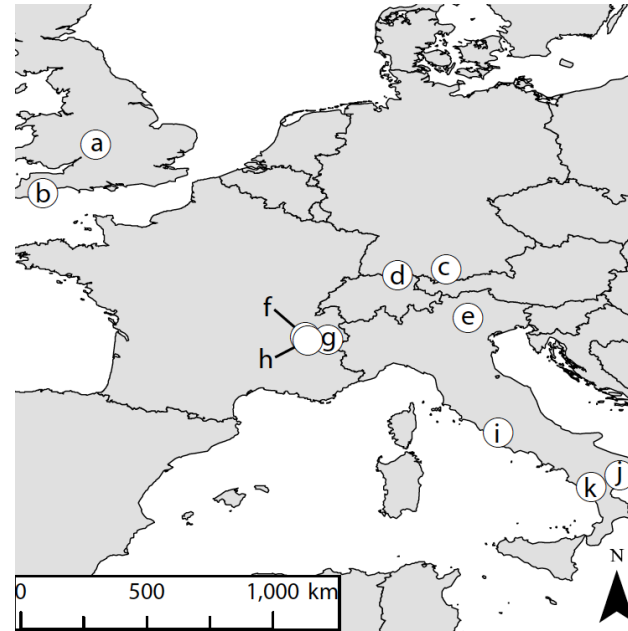


Image velocimetry data available for 13 case studies

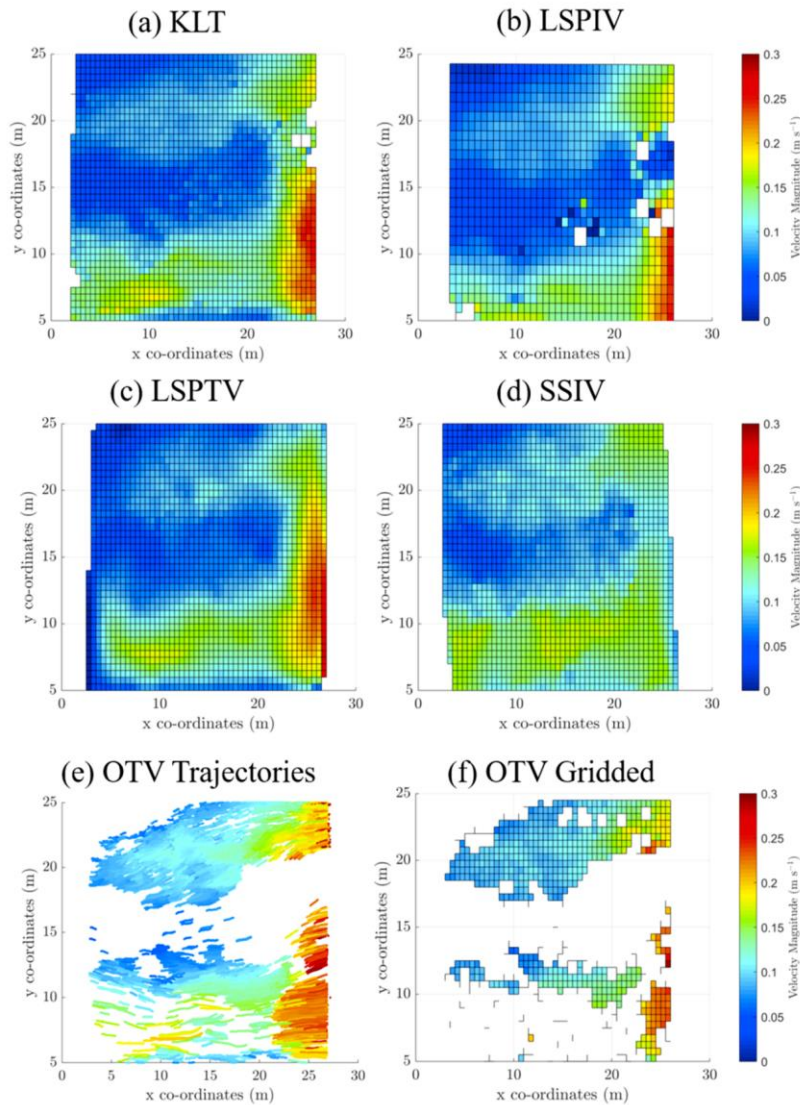


COST is supported by the EU Framework Programme Horizon 2020

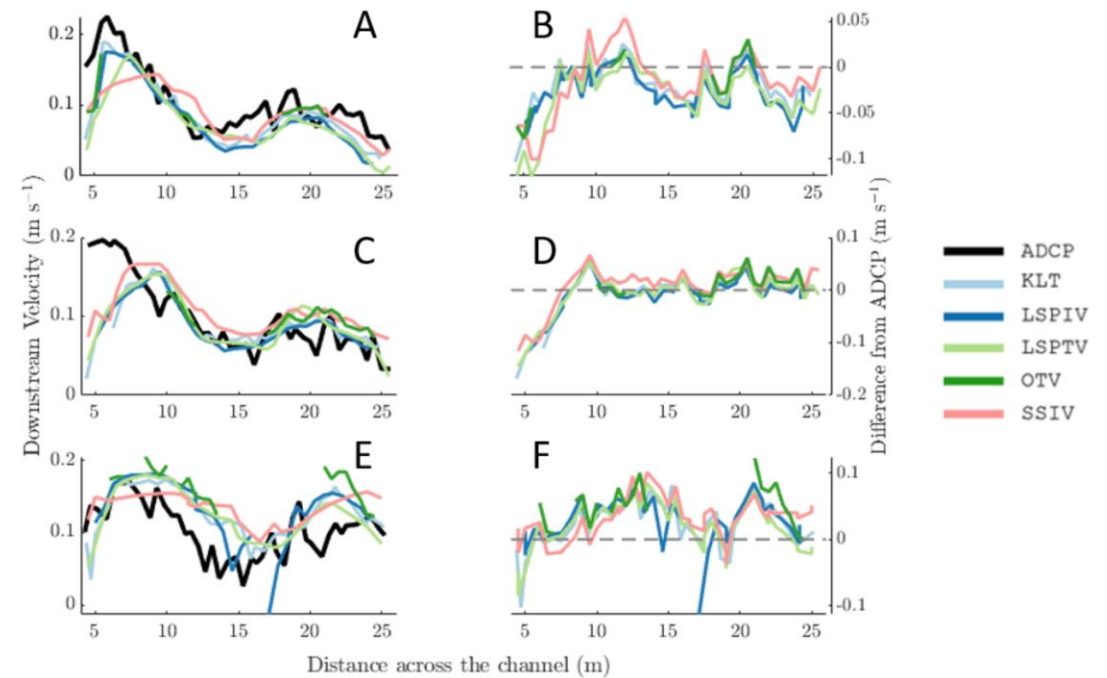
Article: ([Perks et al., ESSD 2019](#))

Data: ([Perks et al., ESSD 2019](#))





Comparison among the most recent Image Velocimetry Techniques

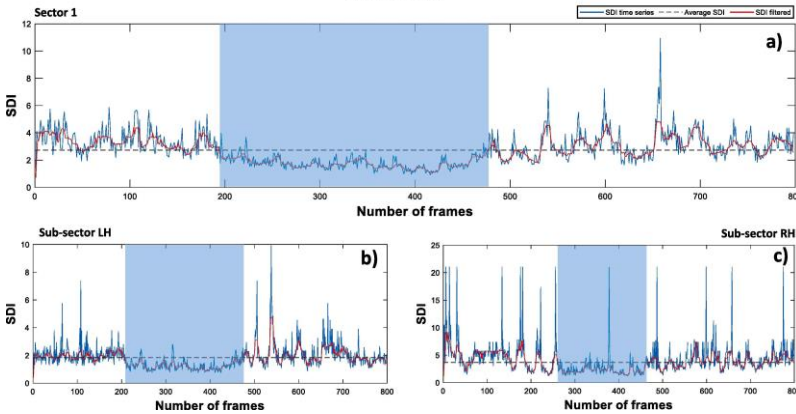


# Identification of the Optimal Frame Window

14



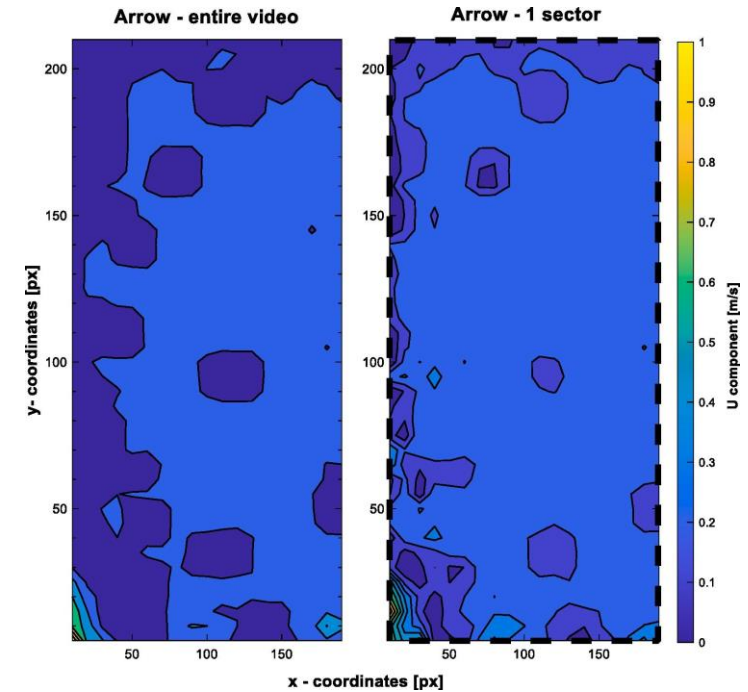
Arrow river



## Seeding Distribution Index

$$SDI = \nu^{0.1} / \left( \frac{\rho}{\rho_{cv1}} \right)$$

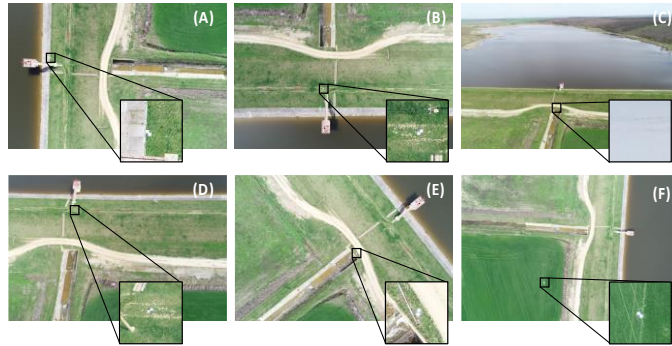
where  $\nu$ ,  $\rho$ , and  $\rho_{cv1}$  are the spatial-clustering level, the seeding density, and the reference seeding density at  $\nu=1$ .



(Pizarro et al., 2020; Dal Sasso et al. 2021)



# UAS data Collection: How to improve DSM accuracy



Flight	Flight plan	Level Above the Ground (m)	Camera Tilt (degree)	Avg GSD (cm/px)	Images
N.1		60	0°	1.9	276
N.2		60	0°	1.9	268
N.3		60	70°	-	271
N.4		60	20°	2.0	273
N.5		60	0°	1.9	257
N.6		120	0°	3.3	85

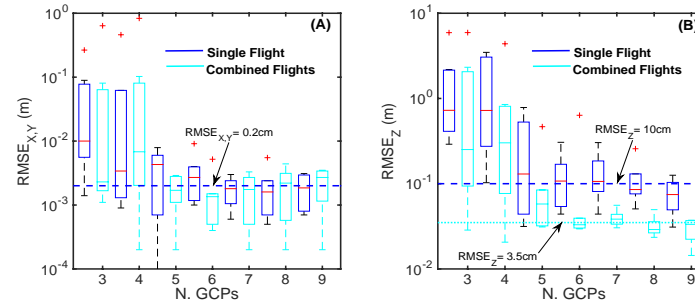


Fig. 1

Fig. 1: Comparison of results obtained changing the number of GCPs and adopting a single flight or a two flights dataset on the plane (A) and z-axis (B).

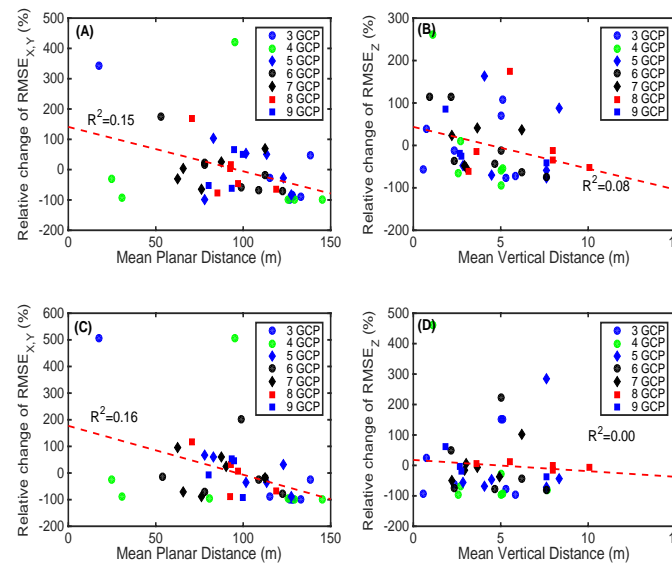


Fig. 2

Fig. 2: RMSE of the 3D model as a function of the mean distance between GCPs obtained for the flight N.2 (A, B) and for the combination of flights N.1 and N.4 (C, D).



([Manfreda et al., Drones 2019](#))

# Guidelines for UAS-based monitoring



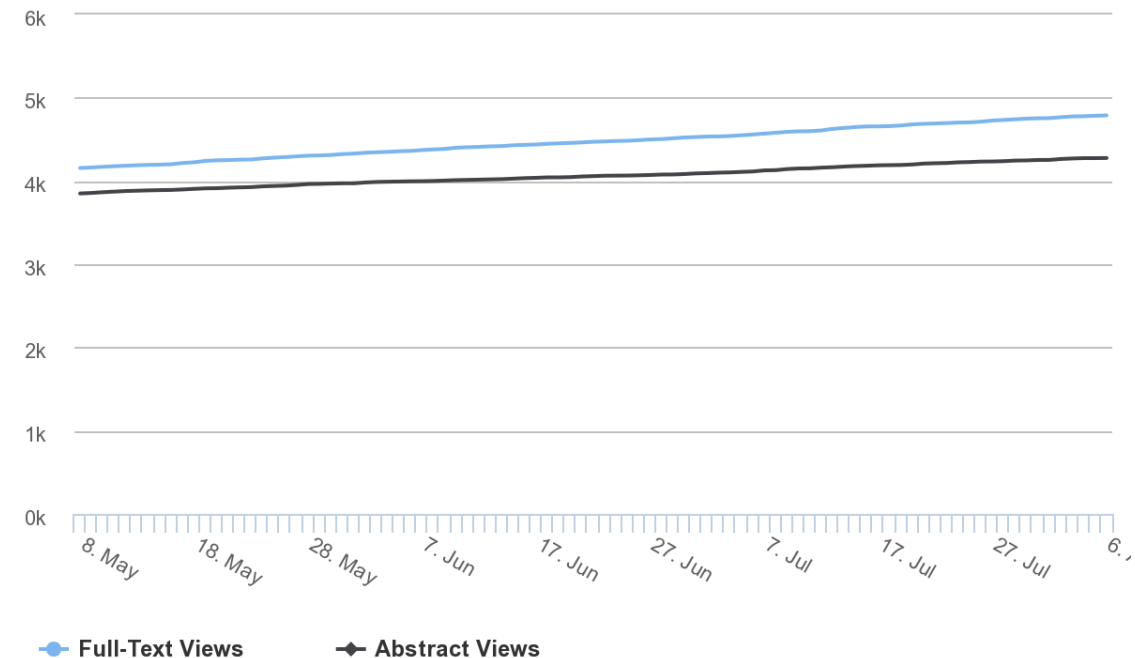
Review

## Current Practices in UAS-based Environmental Monitoring

Goran Tmušić<sup>1</sup>, Salvatore Manfreda<sup>2,\*</sup>, Helge Aasen<sup>3</sup>, Mike R. James<sup>4,5</sup>, Gil Gonçalves<sup>6</sup>, Eyal Ben-Dor<sup>7</sup>, Anna Brook<sup>8</sup>, Maria Polinova<sup>8</sup>, Jose Juan Arranz<sup>9</sup>, János Mészáros<sup>10</sup>, Ruodan Zhuang<sup>11</sup>, Kasper Johansen<sup>12</sup>, Yoann Malbeteau<sup>12,13</sup>, Isabel Pedroso de Lima<sup>14</sup>, Corine Davids<sup>15</sup>, Sorin Herban<sup>16</sup> and Matthew F. McCabe<sup>12</sup>

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Article access statistics

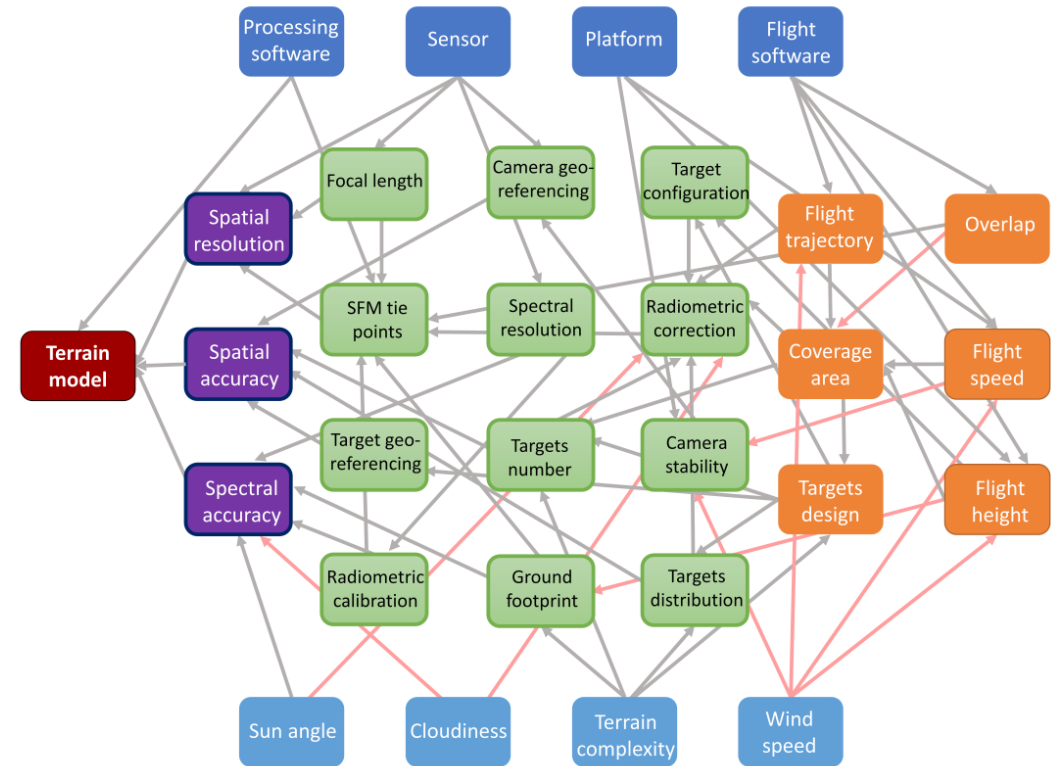


([Tmušić et al., Remote Sensing 2020](#))



# The influence of various study conditions on the output quality of a UAS observation

- output product
- quality parameters
- software and hardware
- experiment design
- environmental conditions
- internal (affected) parameters

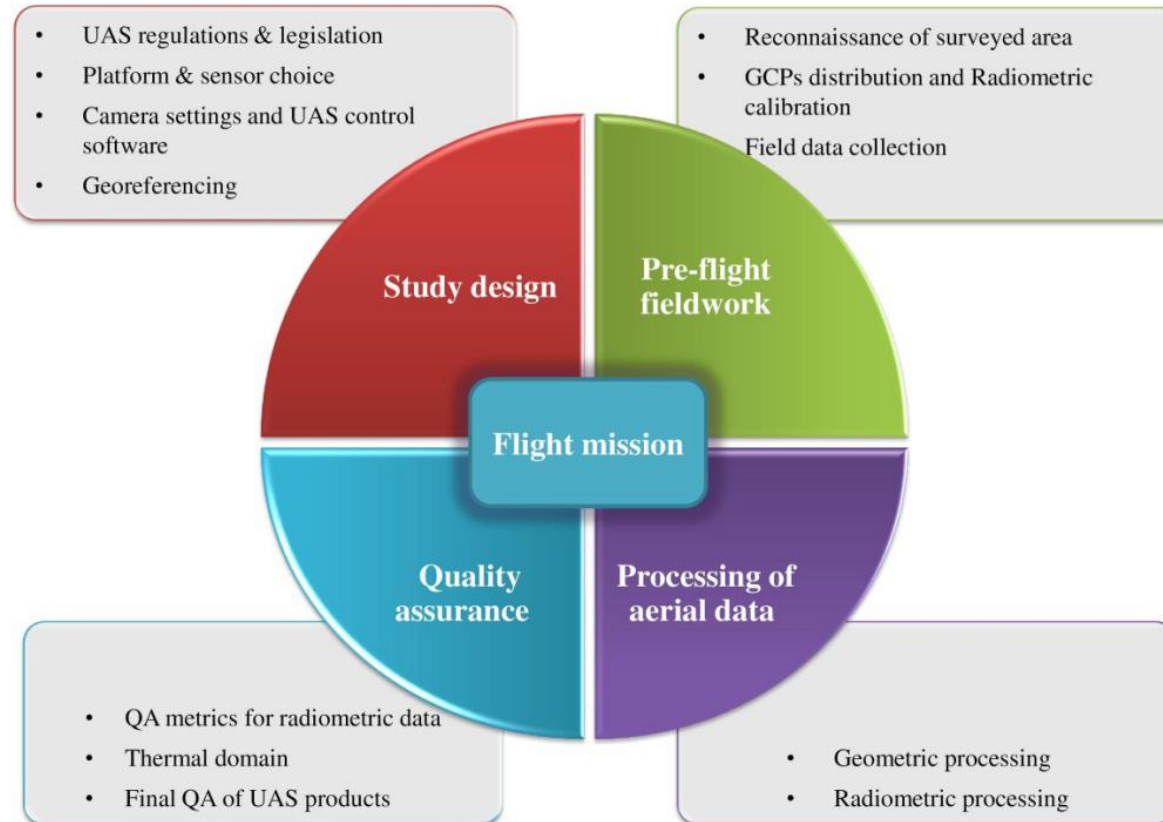


NB: The arrow color indicates the type of relationship: gray - direct dependence, orange - inverse dependence.

([Tmušić et al., Remote Sensing 2020](#))



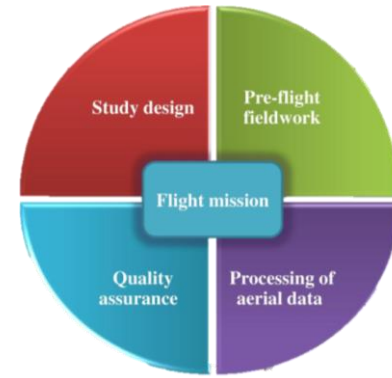
# Activities involved in UAS-based Mapping



([Tmušić et al., Remote Sensing 2020](#))



# Preliminary Checklist before Flying



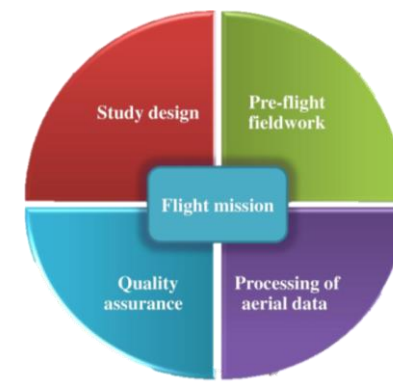
N.	HARMONIOUS UAS Check-List	Check
1	Check the weather conditions (particularly critical maybe rain and strong wind)	
2	Identify the timing of the flight with respect to the best solar illumination. The central hours of the day allow avoiding shadows in the scene.	
3	Make sure that you have GPS coverage to fly in “safe” mode.	
4	Take off from areas that are sufficiently large, free of obstacles and leveled	
5	Check the presence of any deformation to the propeller or frames	
6	Execute a small manual flight; this ensures that the vehicle is stable and radio control is performing well	
7	If the presence of people and / or animals is planned in the survey area, plan the flight when such presence is minimum.	
8	In the case of critical operations, obtain all permits in advance	
9	Check the status of the batteries of your drone, controller, sensors, and tablet	
10	Check that the propellers are intact and well-fixed	
11	Deactivate for safety the Bluetooth and the Wi-Fi of your device (we recommend the mode “Airplane”)	
12	Check that you have enough free memory in the SD card used to store the data acquired	
13	Do the compass calibration (magnetic compass)	
14	Wait for the drone to connect to as many satellites as possible (minimum required 5)	
15	Set the “return to home” point in case of anomaly before starting	
16	<b>Take off and Fly</b>	

# Metadata Associated with each UAS-survey

A detailed description of the flight characteristics and pre-processing activities carried out on the published data is extremely useful, not only for scientific reproducibility, but also to guarantee a certain quality, while also advancing and educating the broader field.

All potential variables and details about a survey are listed in the UAS survey form reported herein.

		Platform type	
	Platform characteristics	Weight & payload capacity	
		Maximum speed	
		Flight height & coverage	
		On-board GNSS receiver	
	Sensor characteristics	Sensor type & name	
		Sensor weight	
Study design	Camera settings	Pixel size	
		Sensor size	
		Focal length	
		ISO	
		Aperture	
	Flight plan	Shutter Speed	
		GSD (cm)	
		Flight height	
			Flight speed
			Forward & side image overlap
	UAS Control software	Software name	
	Georeferencing	Type of georeferencing	
		Number of GCPs	
		Arrangement of GCPs	
Flight mission	Weather	Wind power & direction	
		Illumination condition	
		Humidity	
	Mission	Average flying speed	
		Flying time	
		Flight pattern	
		Camera angle	
Image format			
Processing of aerial data	Geometric processing	SfM tool name	
		Final product type	
		Bundle adjustment	
		Signal to noise ratio	
	Radiometric processing	Radiometric resolution	
		Viewing geometry	
		Band configuration	
		Reflectance calculation method	
Vignetting			
		Motion blur	
Accuracy assessment		Error measure	
		Statistical value	
		Error management	
		Classification accuracy	



# Training Courses of Harmonious: Video Lectures



**Course Introduction**



**Harmonious Action**



**Advances on UAS**



**Guidelines for UAS mapping**



**Soil Mapping**



**Soil Moisture Retrievals**



**Vegetation Mapping**



**River Monitoring**

# Book on UAS Monitoring of Soil-Water-Plant Interactions

## Table of Contents

Introduction

Chapter 1. Remote Sensing of the Environment Using UAS

Chapter 2. Protocols for UAS-based observations

Chapter 3. Using Structure from Motion workflows for 3D Mapping and Remote Sensing

Chapter 4. Vegetation mapping and monitoring by UAS - current state and perspectives

Chapter 6. Monitoring Agricultural Ecosystems

Chapter 7. Mapping soil properties for UAS-based environmental monitoring

Chapter 8. Soil Moisture Content (SMC) monitoring using UAS

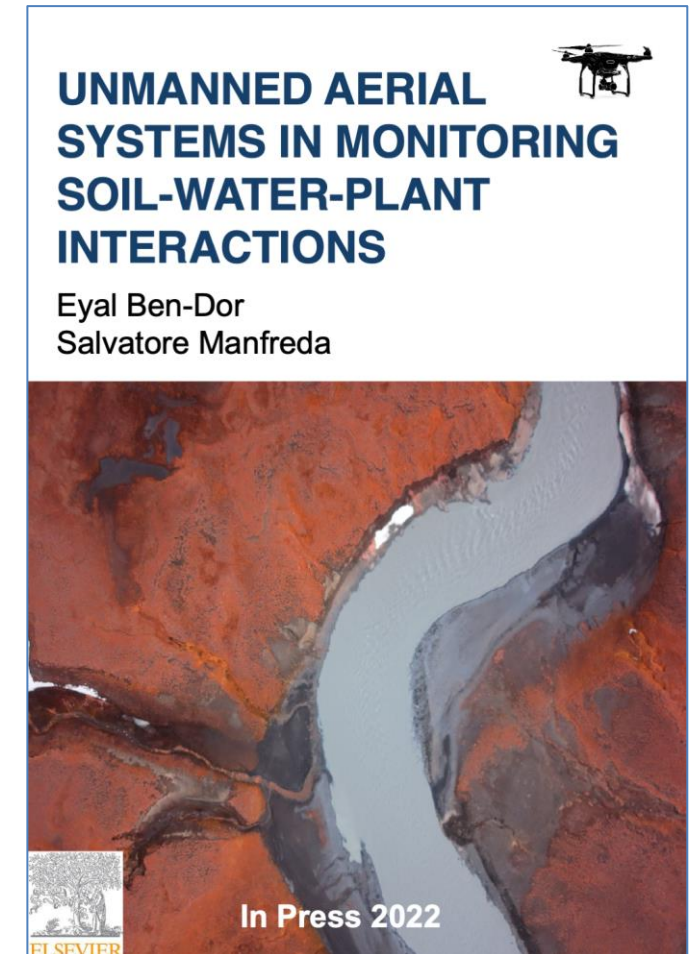
Chapter 9. Geometric correction and stabilisation of images collected by UAVs in river monitoring

Chapter 10. River flow monitoring with UAS

Chapter 11. Monitoring of river channel dynamics by UAS

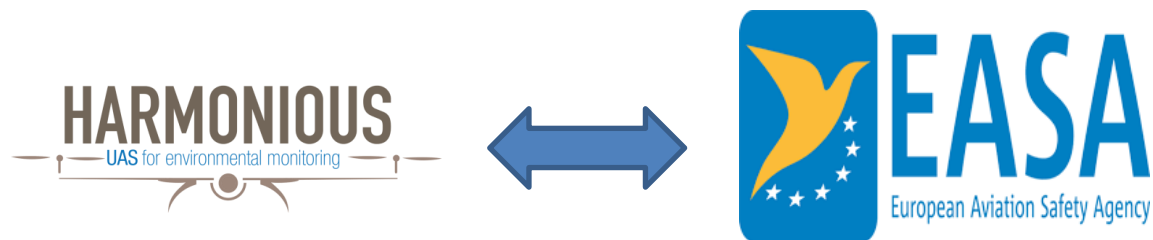
Chapter 12. Tools and datasets for UAS applications

Appendix



# OPERATIONS MANUAL for the use of UAS in ENVIRONMENTAL STUDIES

- Section I - OPERATIONS MANUAL
- Section II - CONCEPT of OPERATIONS
- Section III - EMRGENGY RESPONSE PLAN (ERP)



## Final Remarks

- UAS-based remote sensing provides new advanced procedures to monitor key variables, including vegetation status, soil moisture content, and stream flow.
- The detailed description of such variables will increase our capacity to describe water resource availability and assist agricultural and ecosystem management.
- HARMONIOUS COST Action is supporting the definition of standardized protocols for UAS-based applications to improve reliability of such technology.
- Aim of the next activities is to specialize these guidelines on specific aspects and build new tools to support the use of UAS for environmental monitoring.



# Publications produced by the COST Action HARMOIOUS

- Francos, N., N. Romano, P. Nasta, et al. **Mapping Water Infiltration Rate Using Ground and UAV Hyperspectral Data: A Case Study of Alento, Italy**. Remote Sensing, 2021.
- Ljubičić, R., D. Strelnikova, M.T. Perks, et al. **A comparison of tools and techniques for stabilising UAS imagery for surface flow observations**, Hydrology and Earth System Sciences, 2021.
- Petropoulos, G.P., A. Maltese, T. N. Carlson, et al. **Exploring the use of UAVs with the simplified “triangle” technique for Soil Water Content and Evaporative Fraction retrievals in a Mediterranean setting**, International Journal of Remote Sensing, 2021.
- Pizarro, A., S.F. Dal Sasso, M. Perks and S. Manfreda, **Identifying the optimal spatial distribution of tracers for optical sensing of stream surface flow**, Hydrology and Earth System Sciences, 2020.
- Pizarro, A., S. F. Dal Sasso, S. Manfreda, **Refining image-velocimetry performances for streamflow monitoring: Seeding metrics to errors minimisation**, Hydrological Processes, 2020.
- Paruta, A., P. Nasta, G. Ciruolo, et al. **A geostatistical approach to map near-surface soil moisture through hyper-spatial resolution thermal inertia**, IEEE Transactions on Geoscience and Remote Sensing, 2020.
- Perks, M. T., S. F. Dal Sasso, A. Hauet, et al. **Towards harmonization of image velocimetry techniques for river surface velocity observations**, Earth System Science Data, 2020.
- Tmušić, G., S. Manfreda, H. Aasen, et al. **Current Practices in UAS-based Environmental Monitoring**, Remote Sensing, 2020.
- Pearce, S., R., R. Ljubičić, S. Peña-Haro, et al. **An Evaluation of Image Velocimetry Techniques under Low Flow Conditions and High Seeding Densities Using Unmanned Aerial Systems**, Remote Sensing, 2020.
- Manfreda, S., S. F. Dal Sasso, A. Pizarro, F. Tauro, **Chapter 10: New Insights Offered by UAS for River Monitoring**, Applications of Small Unmanned Aircraft Systems: Best Practices and Case Studies, CRC Press, Taylor & Francis Groups, 2019.
- Manfreda, S., M.F. McCabe. **Emerging earth observing platforms offer new insights into hydrological processes**, Hydrolink, 2019.
- Manfreda, S., P. Dvorak, J. Mullerova, et al. **Assessing the Accuracy of Digital Surface Models Derived from Optical Imagery Acquired with Unmanned Aerial Systems**, Drones, 2019.
- Manfreda, S., M. F. McCabe, P. E. Miller, et al. **On the Use of Unmanned Aerial Systems for Environmental Monitoring**, Remote Sensing, 2018.



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UA

# STSM Awarded

1. **Stochastic investigation of the stream flow process to improve monitoring techniques** - P. Dimitriadis - from Greece to Italy
2. **Exploring different procedures and methods to improve 3D reconstruction with SfM** - S. Manfreda - from Italy to Czech Republic
3. **Use of Thermal, multispectral and RGB imagery on UAS to screen for drought responses in different genotypes of wheat and potatoes** - J. Svensgaard - from Denmark to Italy
4. **Flight planning and GCP's distribution A case study of Basento river, Potenza, Italy** - G. Tmusic - from Serbia To Italy
5. **Evaluating different image-velocimetry algorithms** - S. Pearce - from United Kingdom to Italy
6. **Flood ExtReme velOCity Estimations (FEROCE)** - A. Pizarro - from United Kingdom to Italy
7. **Spatio-temporal heterogeneity in vegetation** - J. Mullerova - from Czech Republic to Italy
8. **PIV and PTV model benchmarking for low flow conditions using ADCP data** - R. Ljubičić - from Serbia to Italy
9. **Investigation on stabilization algorithms for UAS velocimetry** - R. Ljubičić - from Serbia to UK
10. **A comparative study of different approaches to retrieve soil moisture and evaporative fluxes from UAV data** - G. Petropoulos - from Greece to Italy
11. **Glossary for UAS users** - Y. Smidov - from Israel to Romania
12. **Protocols for UAS-based observation** - G. Tmusic - from Serbia to Romania
13. **Implementation of Switched Activation Functions-Based Machine Learning Algorithms for Classification and Feature Selection on Forest Images** - Hacı Mehmet Guzey from Turkey to Romania
14. **Develop an understanding of soil erosion and rill/gully volume estimations using Unmanned Aerial Vehicles (UAVs)** - Josie Lynch from UK to Germany
15. **Construction of video series to promote the scientific activities of the COST Action HARMONIOUS** - László Bertalan from Hungary to Italy
16. **Comparison of different UAS-based soil moisture estimation methods** - Angelika Pataki from Hungary
17. **Guidelines for environmental monitoring using UAS** - Teresa Pizzolla from Italy to Romania
18. **Optimization of the parameters in random forest algorithm and results interpretation** - Ruodan Zhuang from Italy
19. **Two-week scientific visit at the Freiburg University** - Carolina Allocca from Italy to Germany
20. **Multispectral sensors and spectral indices for water detection** - Cinzia Albertini from Italy to Greece
21. **River turbidity monitoring using RGB trail camera** - Domenico Miglino from Italy to Germany
22. **Data collection for fluvial geomorphology: Image velocimetry methods** - Martin Jolley from UK to Hungary



# VM Grants

1. Dariia Strelnikova: Creation of a blueprint of an Operations Manual (OM) for UAS based Environmental Studies in compliance with EASA guidelines
2. Eyal Ben-Dor: Unmanned Aerial Systems in Monitoring Soil-Water-Plant
3. George PETROPOULOS: Research collaboration in the project framework
4. Jana Mullerova: Identifying the most important challenges in drone-based environmental studies
5. Maria Tsiafouli: Creating maps of soil ecological functioning combining soil biological and UAV data
6. Qianqian Han: A comparison of different machine learning algorithms for soil moisture estimation at global scale
7. Robert Ljubicic: Overview of image enhancement techniques for UAV image velocimetry
8. Optionsruodan zhuangVM Grant letter sentOptimization of the parameters and recursive feature elimination in random forest algorithm in soil moisture estimation
9. Salvatore ManfredaVM Pre-Approved Unmanned Aerial Systems in Monitoring Soil-Water-Plant
10. Stefana Ioneanu: Creation of a blueprint of an Operations Manual (OM) for UAS based Environmental Studies with respect to European Aviation Safet
11. Teresa Pizzolla: Unmanned Aerial Systems for ecosystems monitoring

