UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

EGU General Assembly 2020

Use of Unmanned Aerial Systems for Hydrological Monitoring

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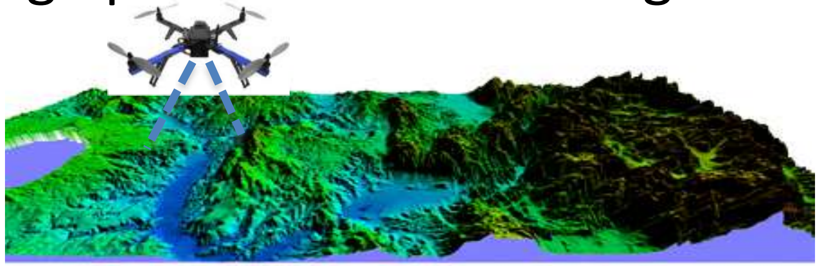
Unmanned Arial Systems (UAS) for Environmental Monitoring

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

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

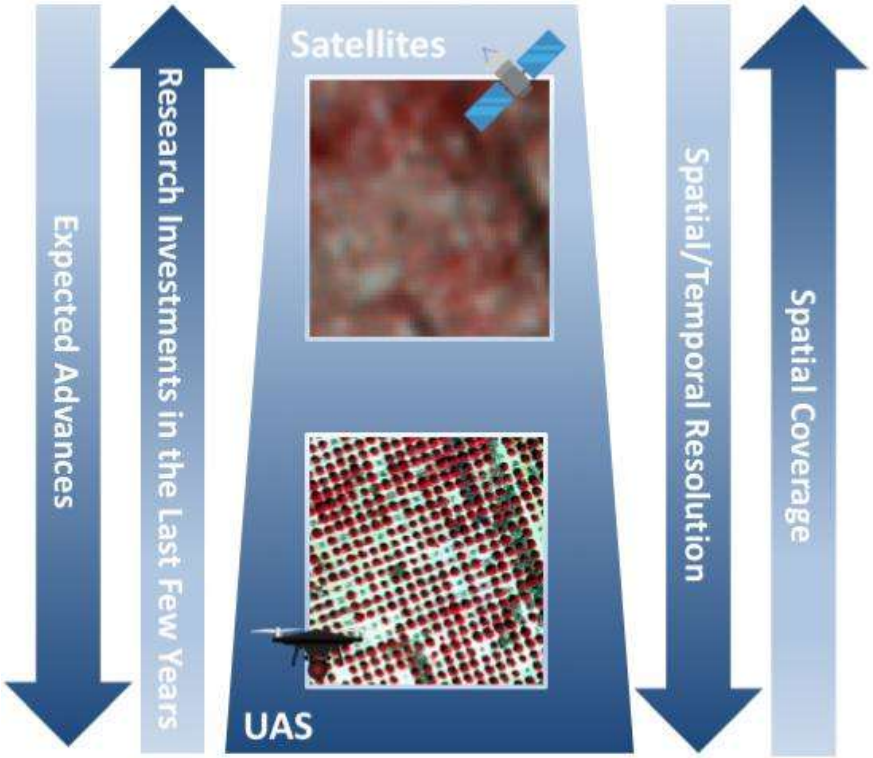


Environmental Monitoring

Global	Few hectars	Few m²
		
Up to 30cm	Up to 1cm	Up to 1cm

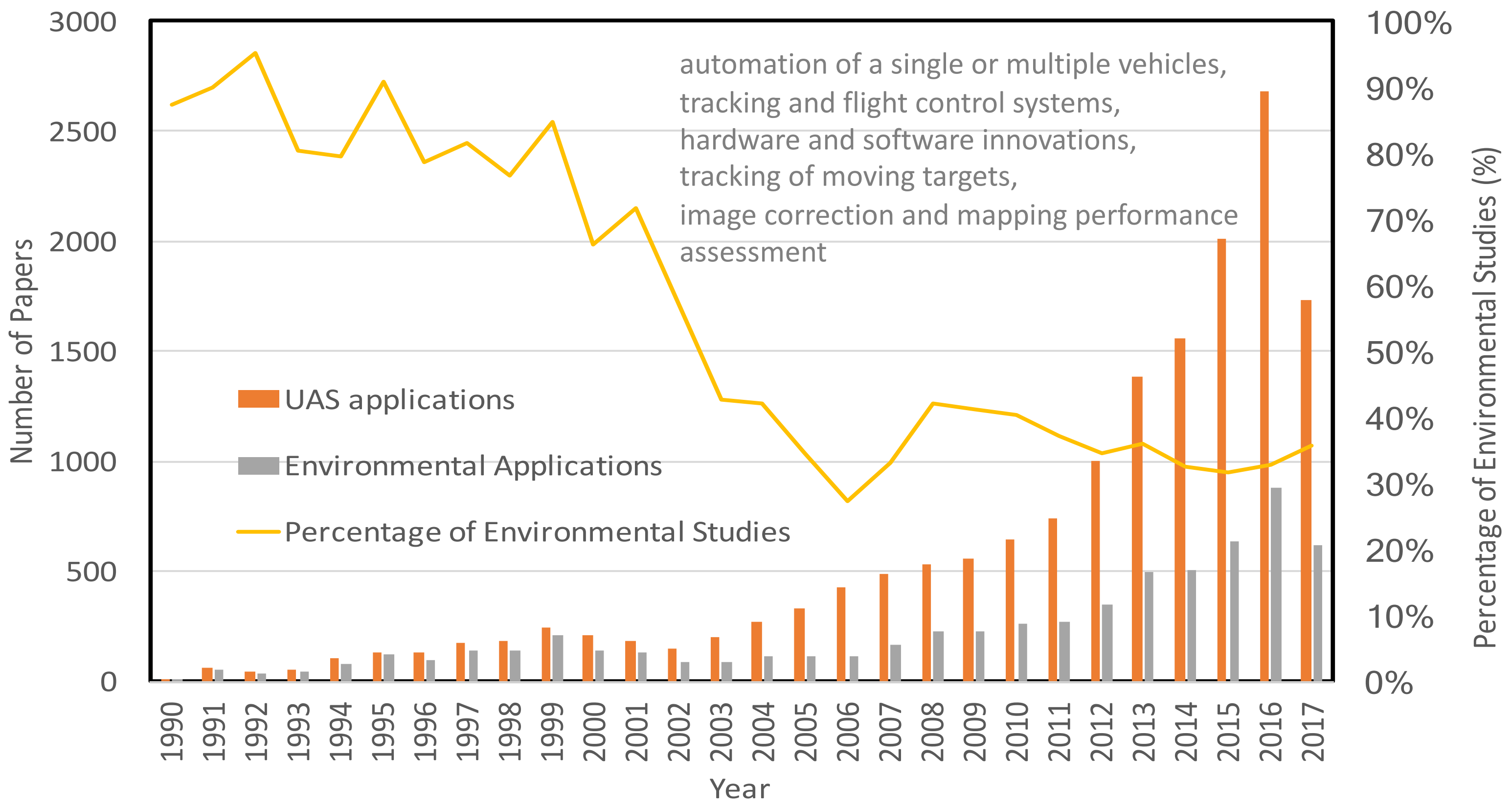
Comparable Scales

UAS vs Satellite



(Manfreda et al., Remote Sensing 2018)

Number of articles extracted from the database ISI web of knowledge



from 1990 up to 2017 (last access 15/01/2018)

(Manfreda et al., Remote Sensing 2018)

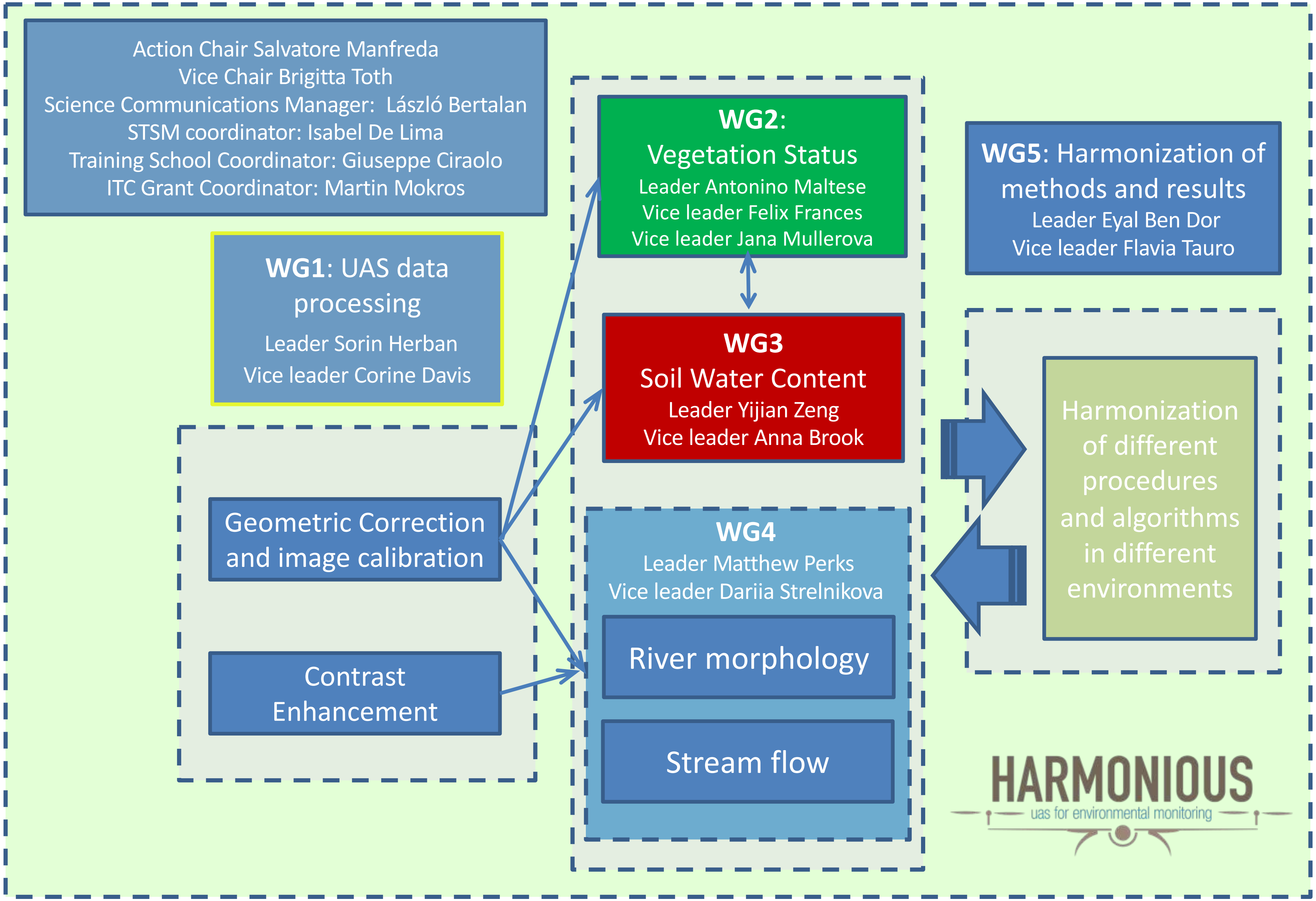
COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

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

HARMONIOUS UAS for environmental monitoring



Action Chair Salvatore Manfreda
Vice Chair Brigitta Toth
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STSM coordinator: Isabel De Lima
Training School Coordinator: Giuseppe Ciraolo
ITC Grant Coordinator: Martin Mokros
WG1: UAS data processing
Leader Sorin Herban
Vice leader Corine Davis
Geometric Correction and image calibration
Contrast Enhancement
WG2: Vegetation Status
Leader Antonino Maltese
Vice leader Felix Frances
Vice leader Jana Mullerova
WG3 Soil Water Content
Leader Yijian Zeng
Vice leader Anna Brook
WG4
Leader Matthew Perks
Vice leader Dariia Strelnikova
River morphology
Stream flow
WG5: Harmonization of methods and results
Leader Eyal Ben Dor
Vice leader Flavia Tauro
Harmonization of different procedures and algorithms in different environments
HARMONIOUS
uas for environmental monitoring

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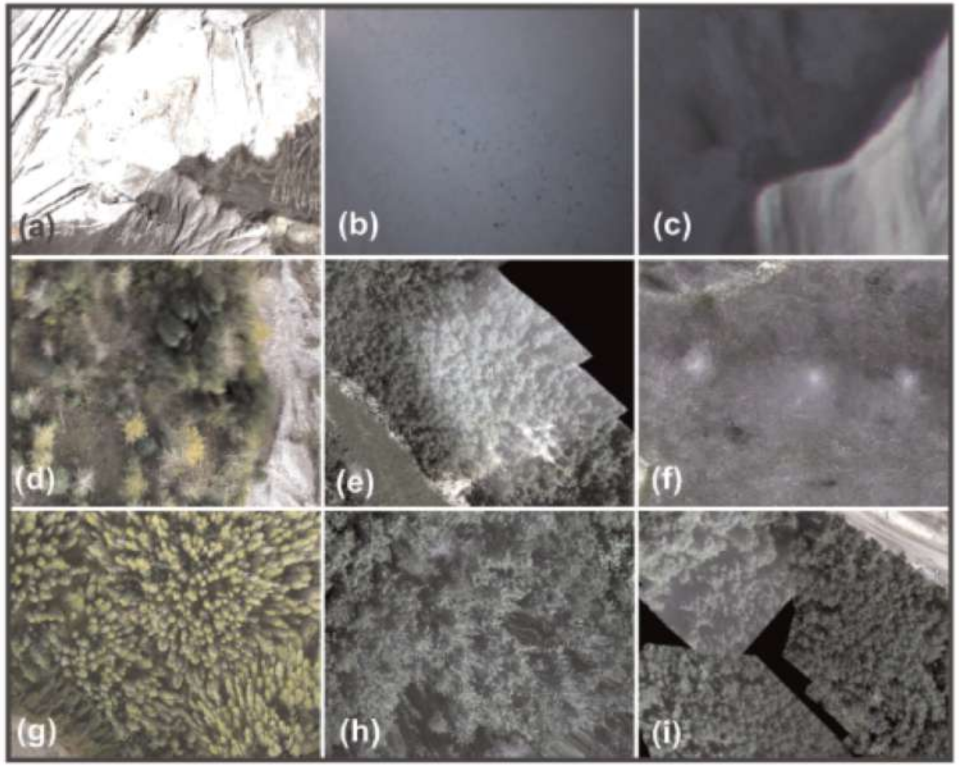
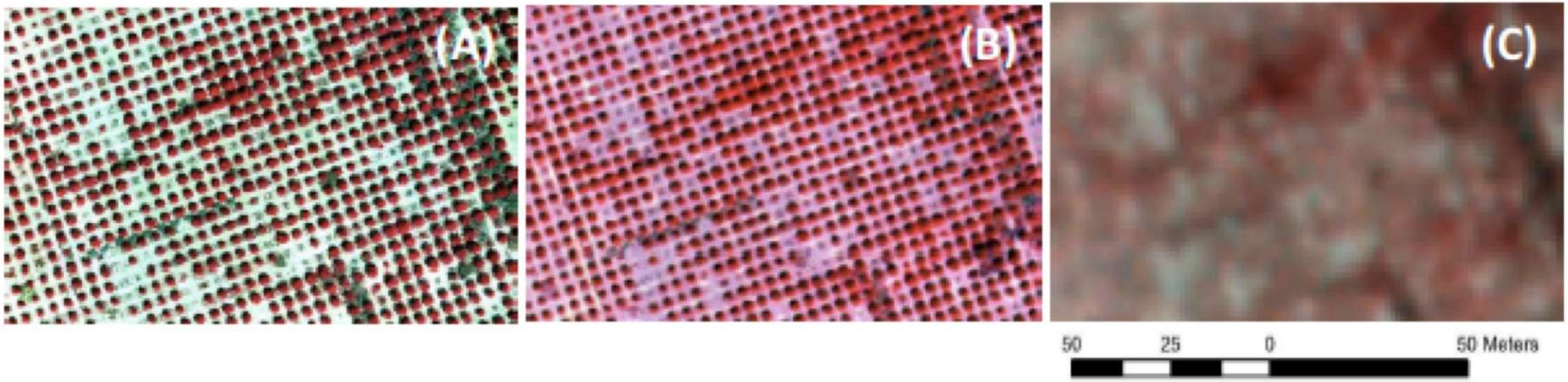
Examples of Common Image Artifacts



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.

(Whitehead and Hugenholtz, 2014)

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), collected on the 13th, 29° and 27th March 2018, respectively.

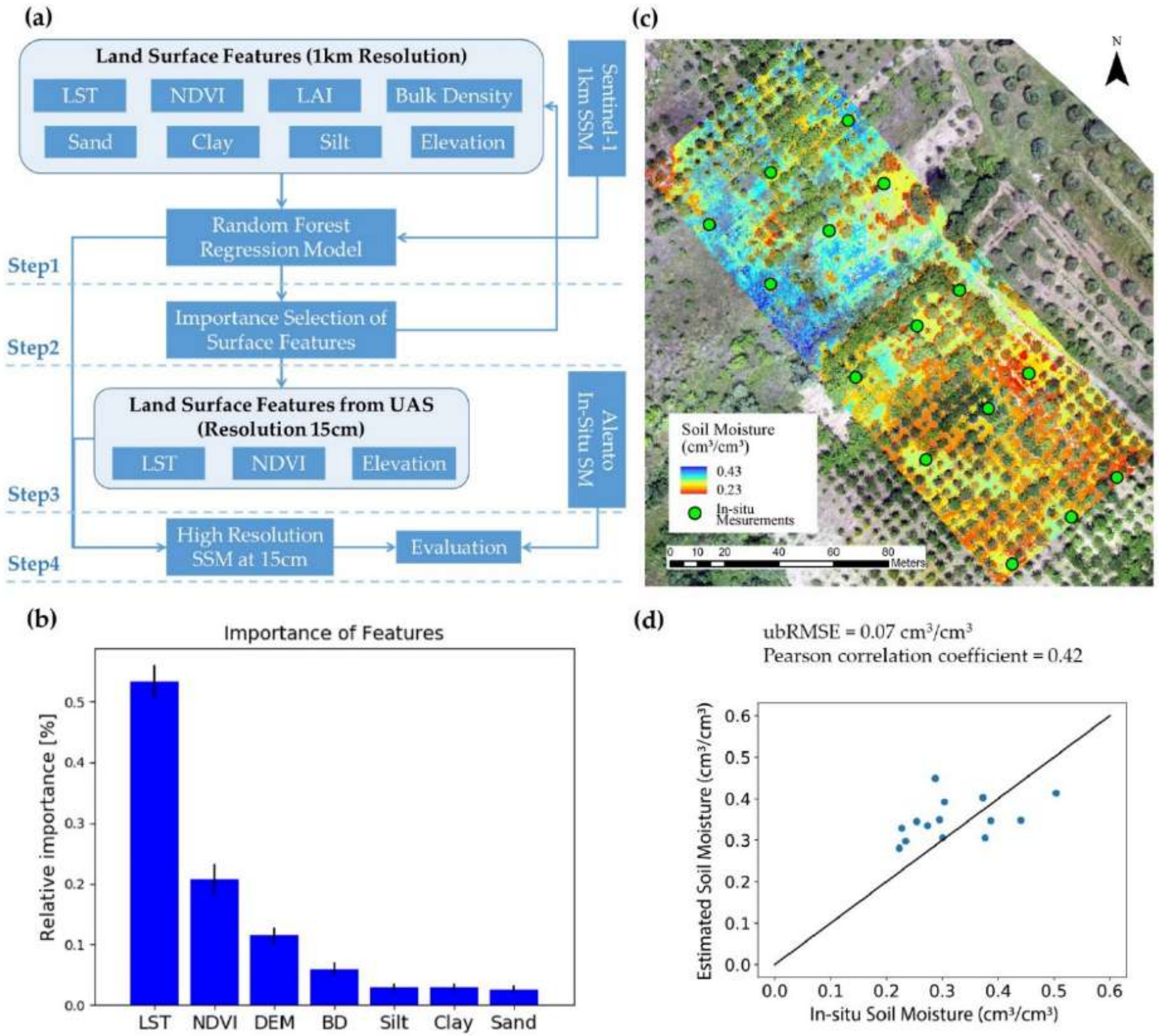
WG3
Soil Water Content Monitoring

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;

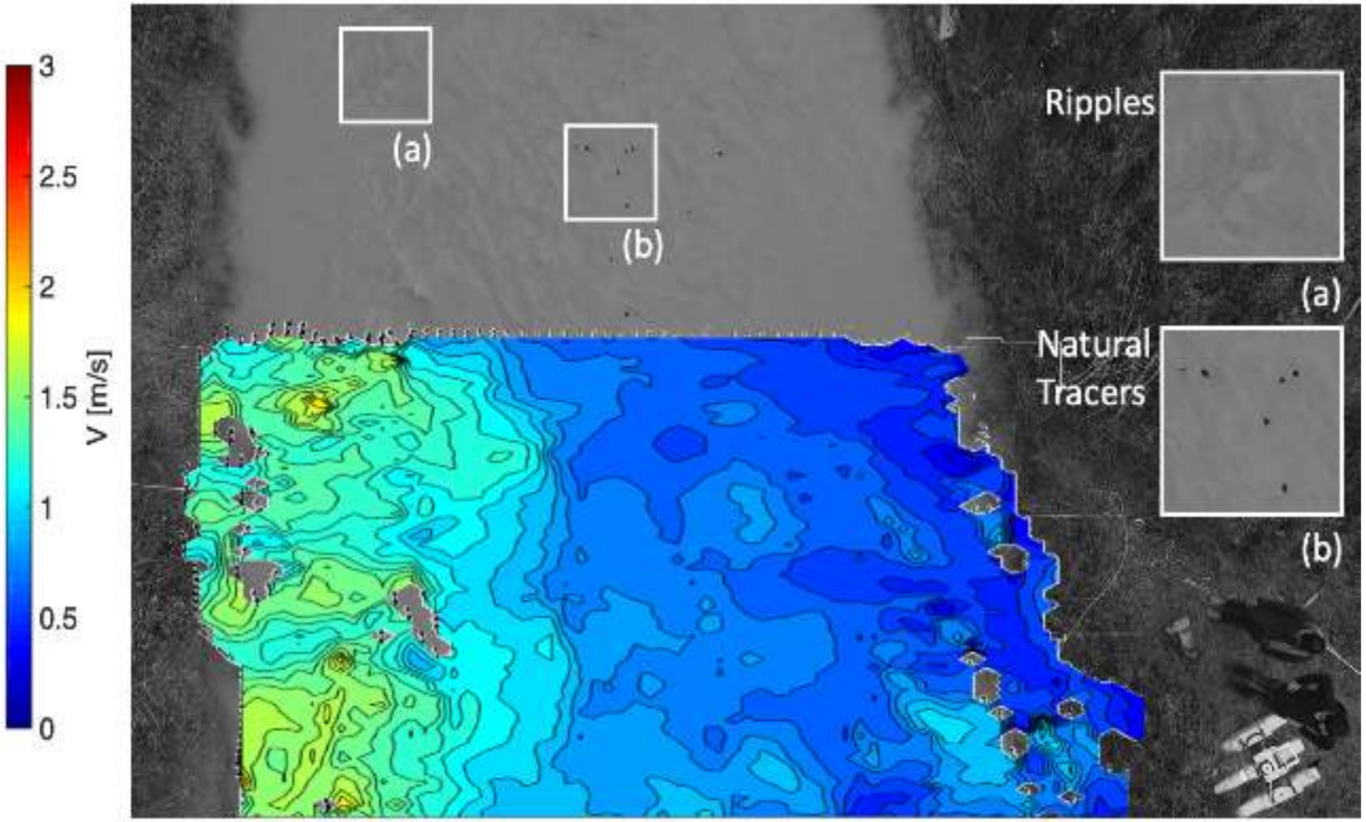
d) Comparison of the downscaled soil moisture with in-situ measurements.



(Su et al., Water 2020)

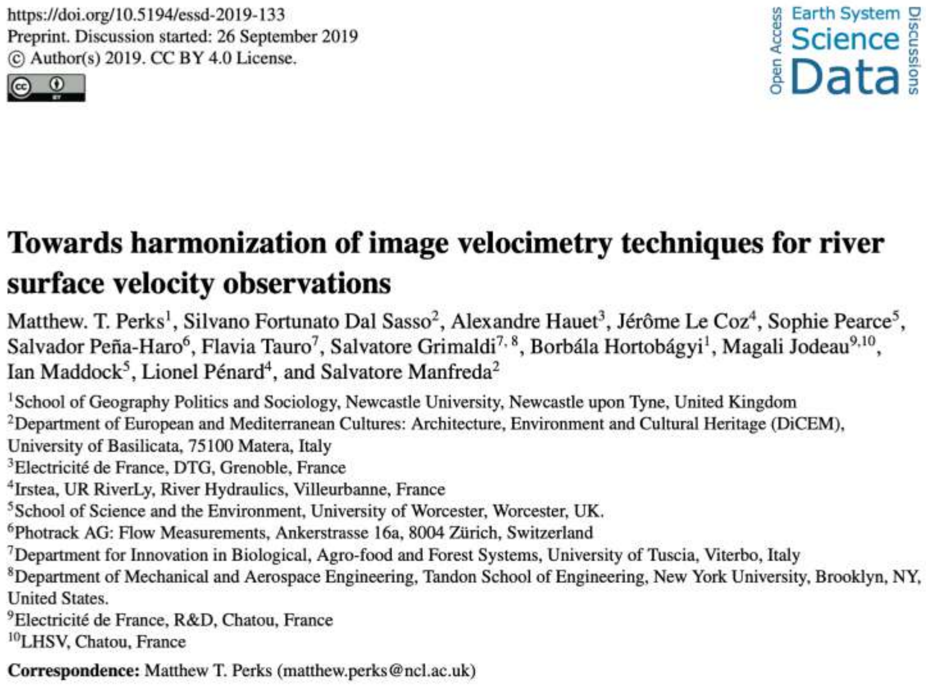
Image Velocimetry

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).



(Manfreda and McCabe, Hydrolink 2019)

Stream Flow Monitoring – Data Collection for Benchmarking Optical Techniques


https://doi.org/10.5194/essd-2019-133
Preprint. Discussion started: 26 September 2019

Open Access Earth System Science Data Discussions

Towards harmonization of image velocimetry techniques for river surface velocity observations

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

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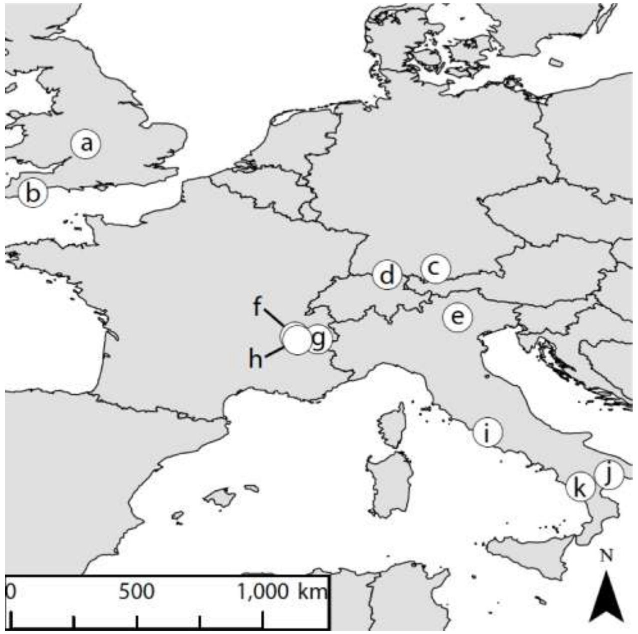


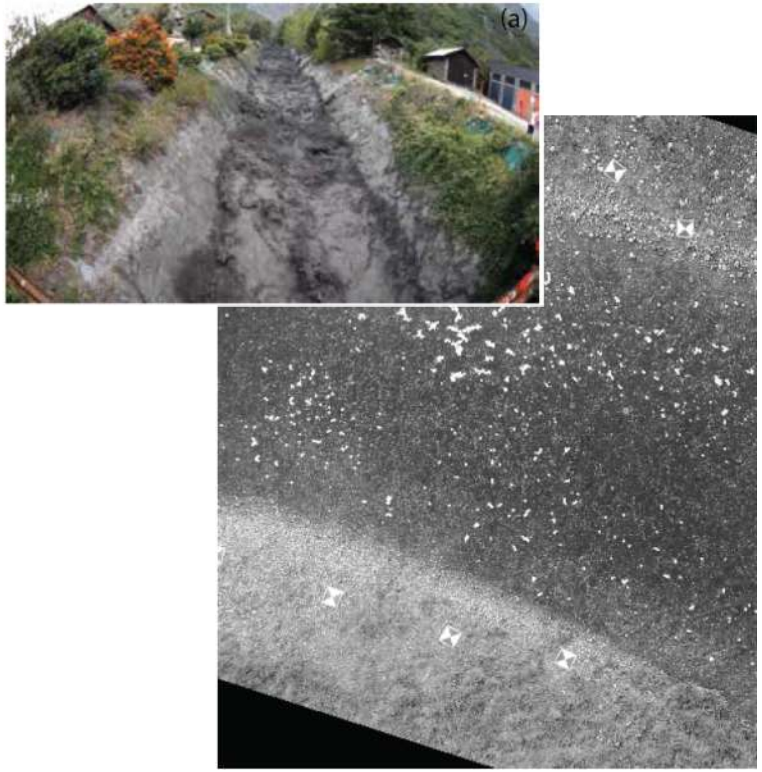
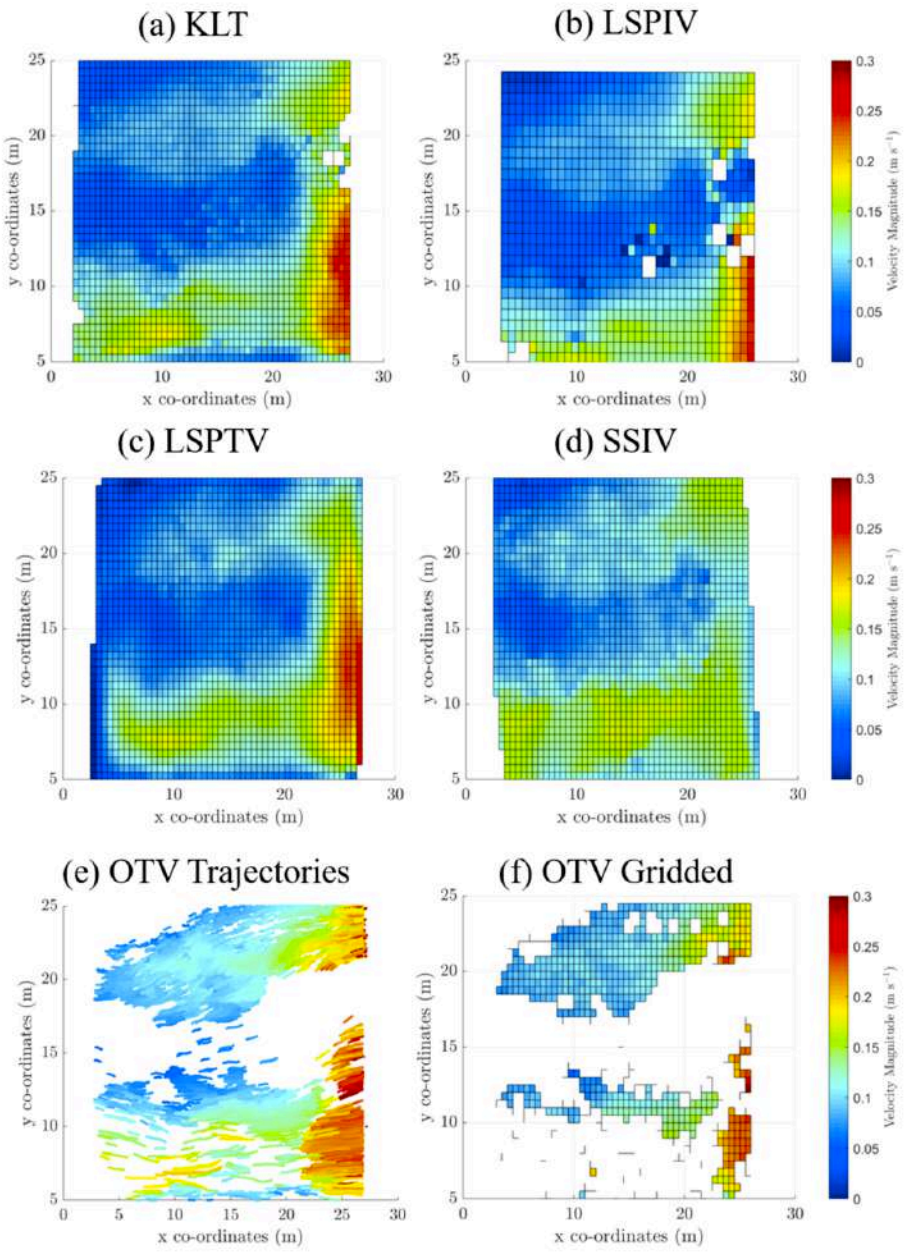


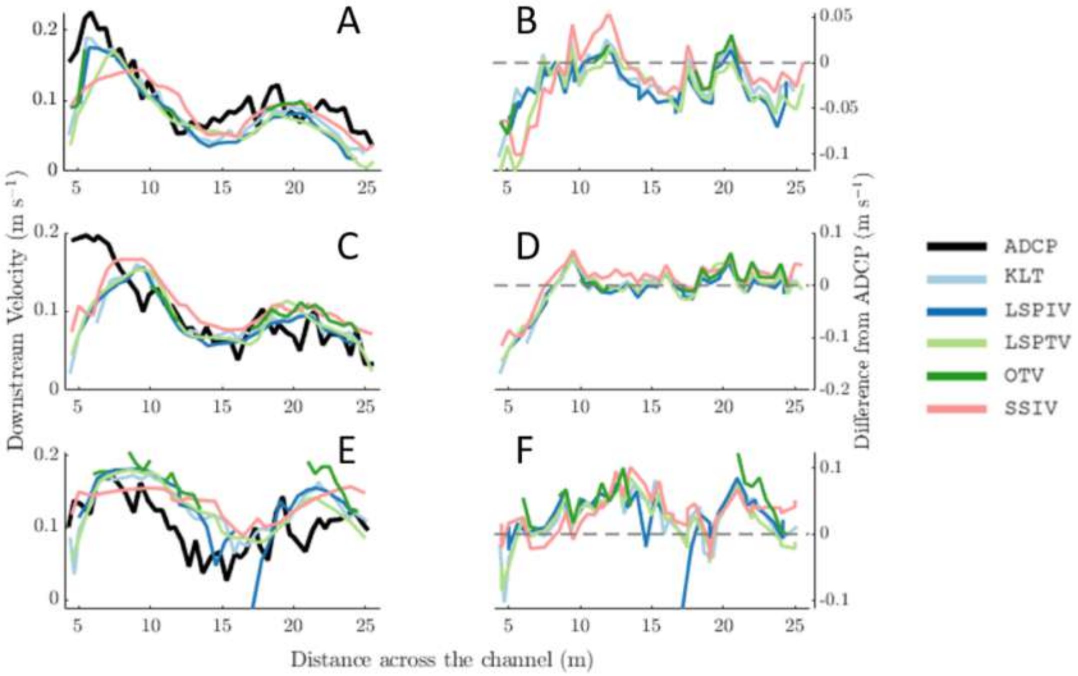
Image velocimetry data available for 13 case studies

Article: (Perks et al., ESSD 2019)
Data: (Perks et al., ESSD 2019)

WG4
River Monitoring

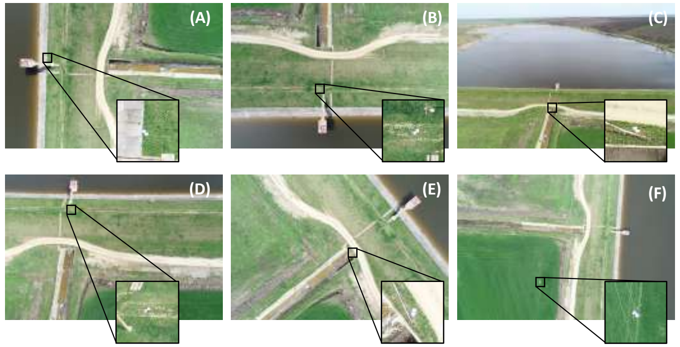


Comparison among the most recent Image Velocimetry Techniques



(Pearce et al., Remote Sensing 2020)

UAS data Collection: How to improve DSM accuracy



Fligth	Fligth 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

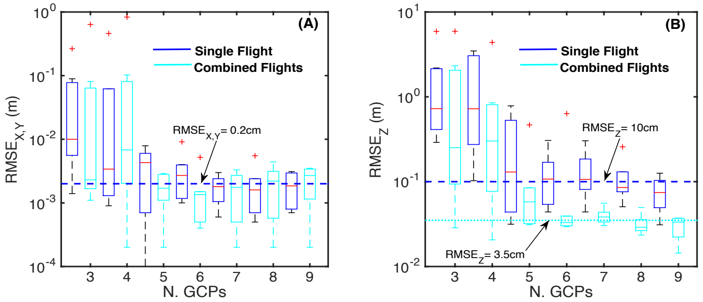


Fig. 1

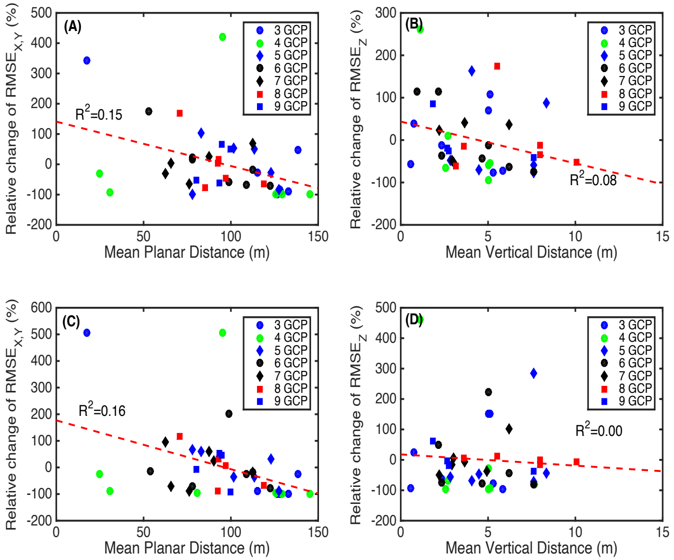


Fig. 2

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-axes (B).

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

remote sensing

MDPI

Review

Current Practices in UAS-based Environmental Monitoring

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

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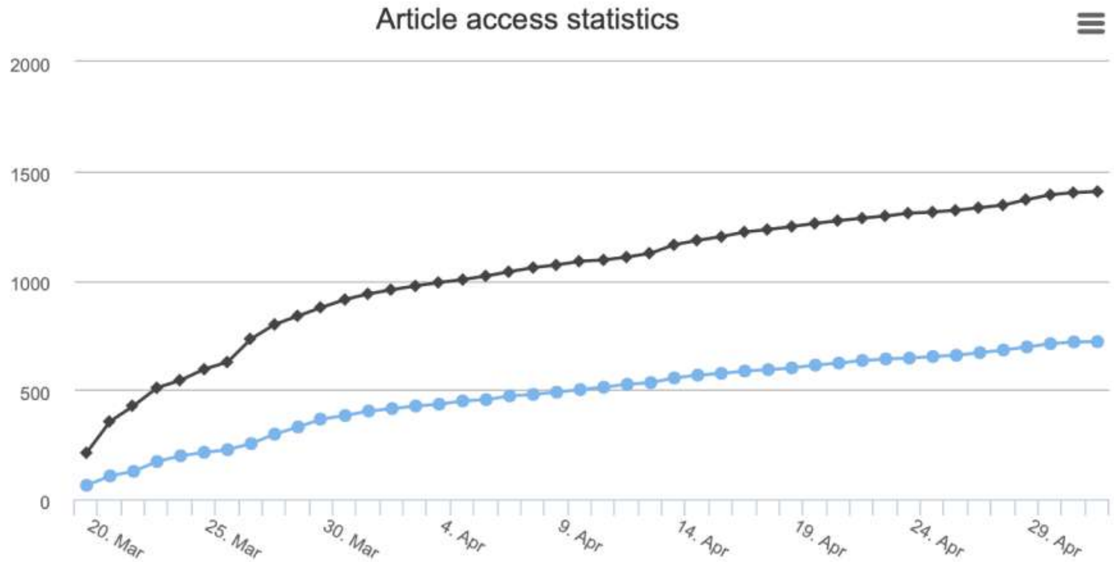
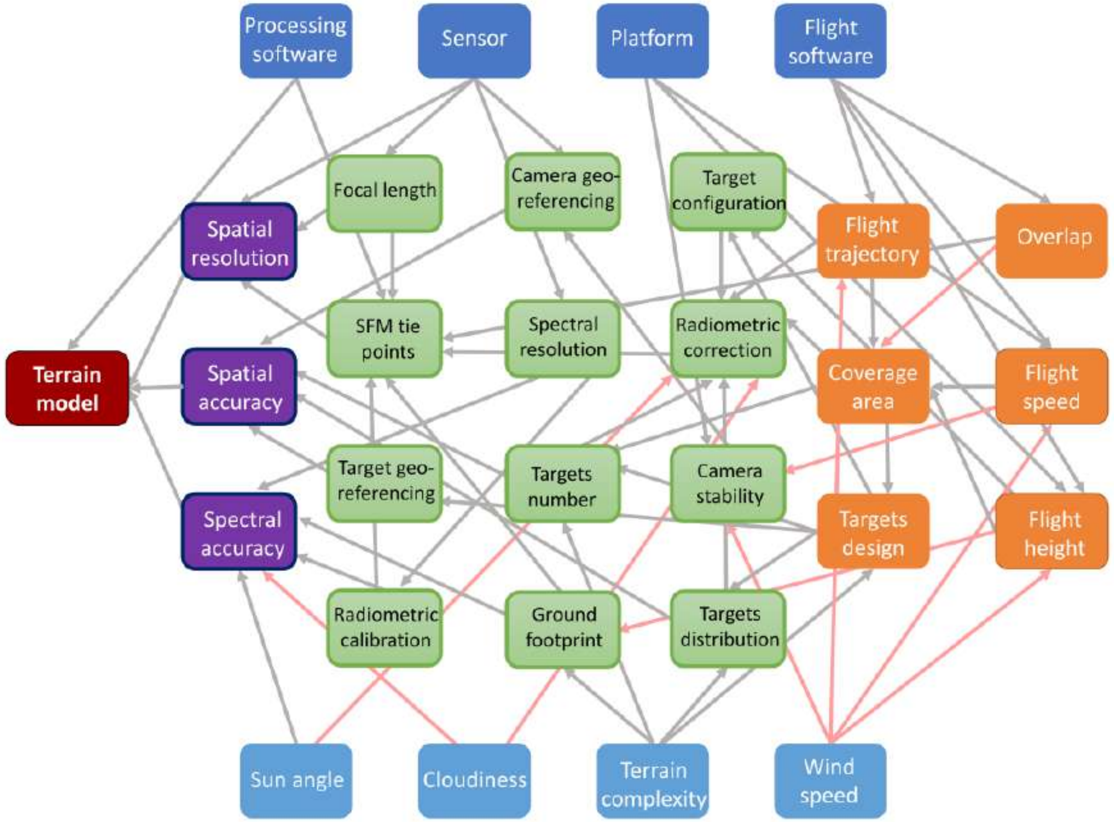


(Tmušić et al., Remote Sensing 2020)

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

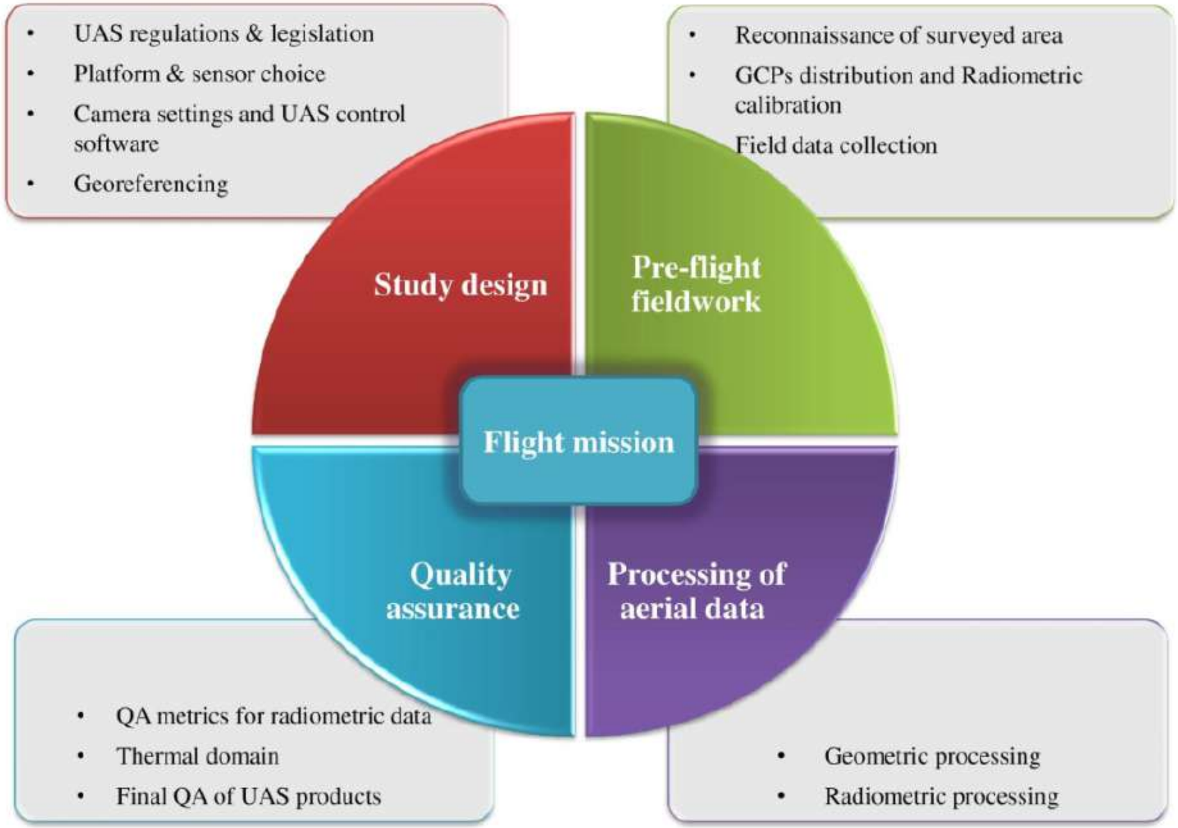
- output product
- quality parameters
- software and hardware
- experiment design
- environmental conditions
- internal (affected) parameters



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)

(Dis)advantages of Different Platforms

Platform	Advantages (+) and Disadvantages (-)	Flight Time/Coverage
Rotary-wing	+ flexibility and ease of use + stability + possibility for low flight heights and low speed + possibility to hover - lower area coverage - wind may affect the vehicle stability	Flight time typically 20–40 min Coverage 5–30 × 10^3 m^2 depending on flight altitude
Fixed-wing	+ capacity to cover larger areas + higher speed and reduced time of flight execution - take-off and landing require an experienced pilot - faster vehicle may have difficulties in mapping small objects or establish enough overlaps	Flight time up to hours Coverage e.g., >20 km^2 depending on flight altitude
Hybrid VTOL (Vertical Take Off and Landing)	+ ability to hover, vertical take-off and landing + ability to cover larger areas - complex systems mechanically (i.e., tilting rotors or wings, mixed lifting and pushing motors)	Flight time up to hours, but usually less than fixed wings Coverage × 10^6 m^2

(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	**Take off and Fly**	

(Tmušić et al., Remote Sensing 2020)

Metadata Associated with each UAS-survey

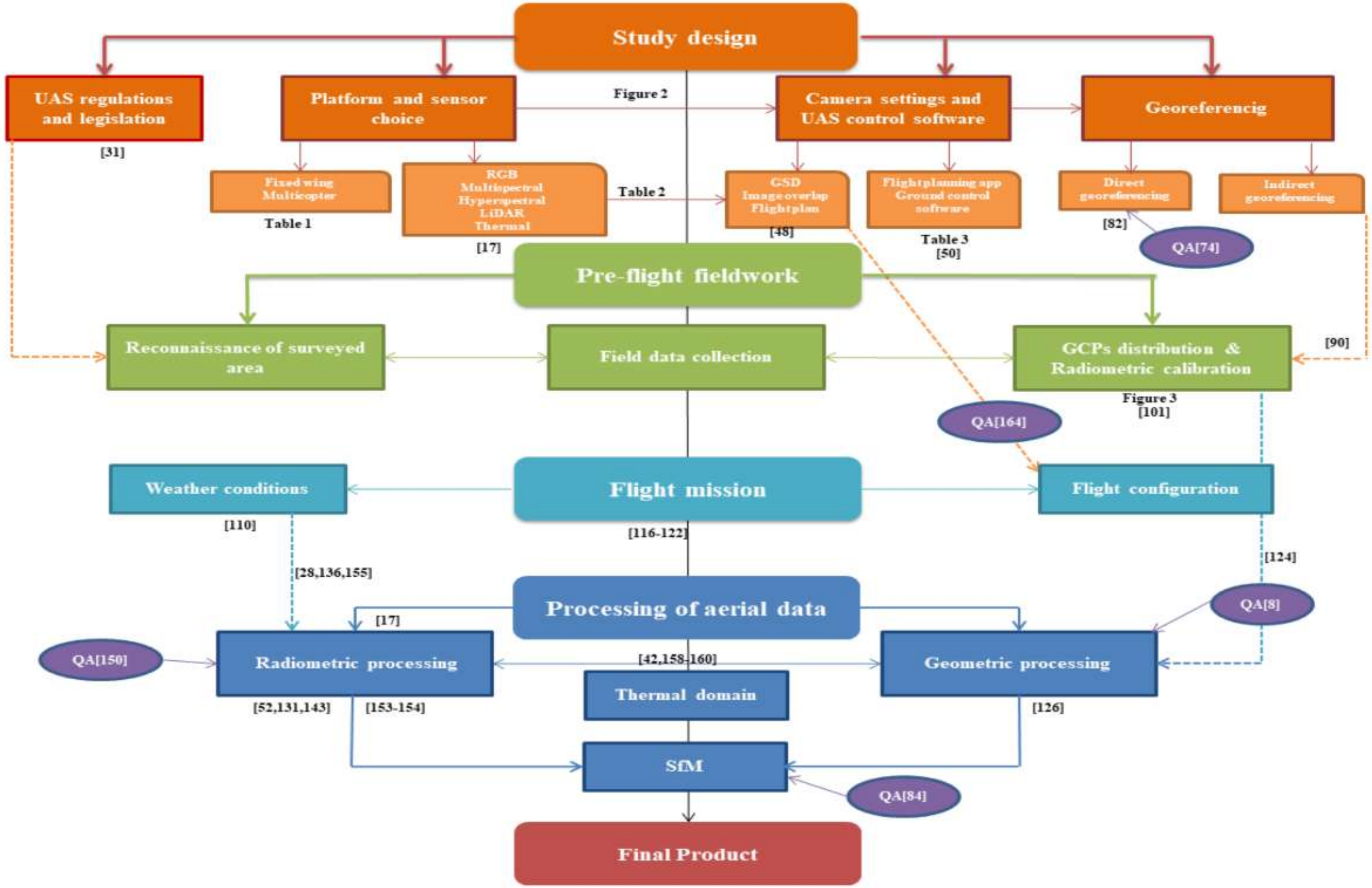
A detailed description of the flight characteristics and preprocessing activities carried out on the published data is extremely useful, not only for scientific reproducibility, but also to guarantee a certain quality, while also advancing and educating the broader field.

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

Study design	Platform characteristics	Platform type
		Weight & payload capacity
		Maximum speed
		Flight height & coverage
		On-board GNSS receiver
	Sensor characteristics	Sensor type & name
		Sensor weight
	Camera settings	Pixel size
		Sensor size
		Focal length
		ISO
		Aperture
		Shutter Speed
	Flight plan	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
	Radiometric processing	Signal to noise ratio
		Radiometric resolution
		Viewing geometry
		Band configuration
		Reflectance calculation method
		Vignetting
		Motion blur
Accuracy assessment		Error measure
		Statistical value
		Error management
		Classification accuracy

(Tmušić et al., Remote Sensing 2020)

Proposed UAS Environmental Mapping Workflow



(Tmušić et al., Remote Sensing 2020)

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.

HARMONIOUS
UAS for environmental monitoring

Publications produced by the COST Action HARMOIOUS

Tmušić, G.; Manfreda, S.; Aasen, H.; James, M.R.; Gonçalves, G.; Ben-Dor, E.; Brook, A.; Polinova, M.; Arranz, J.J.; Mészáros, J.; Zhuang, R.; Johansen, K.; Malbeteau, Y.; de Lima, I.P.; Davids, C.; Herban, S.; McCabe, M.F. **Current Practices in UAS-based Environmental Monitoring**, Remote Sensing, 12, 1001, 2020. **[pdf]**

Pearce, S.;R.; R. Ljubičić; S. Peña-Haro; M. Perks; F. Tauro; A. Pizarro; S.F. Dal Sasso; D. Strelnikova; S. Grimaldi; I. Maddock; G. Paulus; J. Plavšić; D. Prodanović; S. Manfreda, ***An Evaluation of Image Velocimetry Techniques under Low Flow Conditions and High Seeding Densities Using Unmanned Aerial Systems***, Remote Sensing, 12, 232, 2020. **[pdf]**

Perks, M. T., S. Fortunato Dal Sasso, A. Hauet, S. Pearce, S. Peña-Haro, F. Tauro, S. Grimaldi, B. Hortobágyi, M. Jodeau, J. Le Coz, I. Maddock, L. Pénard, and S. Manfreda, ***Towards harmonization of image velocimetry techniques for river surface velocity observations***, Earth System Science Data Discussion, 2019. **[pdf]**

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