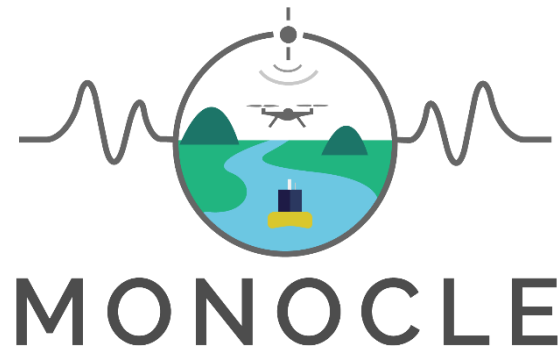


Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
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Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries

Deliverable 3.2

Operational protocols for acquisition and deployment

Project Description

Funded by EU H2020 MONOCLE creates sustainable *in situ* observation solutions for Earth Observation (EO) of optical water quality in inland and transitional waters. MONOCLE develops essential research and technology to lower the cost of acquisition, maintenance, and regular deployment of *in situ* sensors related to optical water quality. The MONOCLE sensor system includes handheld devices, smartphone applications, and piloted and autonomous drones, as well as automated observation systems for e.g. buoys and shipborne operation. The sensors are networked to establish interactive links between operational Earth Observation (EO) and essential environmental monitoring in inland and transitional water bodies, which are particularly vulnerable to environmental change.



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

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Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

TABLE OF CONTENTS

1. Executive Summary	7
2. Scope	7
3. Introduction	8
4. Overview of MONOCLE systems.....	9
5. Acquisition and deployment protocols	10
5.1 Peak Design Ltd Hyperspectral Radiometer – HSR1	10
System description.....	10
System set-up/Installation.....	10
System check list	10
Field calibration	11
Data gathering	11
Data check	11
Data upload.....	11
System maintenance	11
5.2 Solar-tracking radiometer platform (So-Rad).....	12
System description.....	12
System set-up/Installation.....	15
System check.....	17
Field calibration	18
Data gathering	18
Data check	19
Data upload.....	19
System maintenance	19
5.3 WISPstation	21
System description.....	21
System set-up/Installation.....	23
System check.....	27
Field calibration	27
Data gathering	27
Data check	27
Data upload.....	27
System maintenance	27
5.4 Remotely Piloted Aircraft Systems – RPAS	29
System description.....	29
System set-up/Installation.....	29
System check.....	31



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Field calibration	32
Data gathering	33
Data check	51
Data upload - MAPEO field software	51
System maintenance	62
5.5 iSPEX 2.....	63
System description.....	63
System set-up/Installation.....	63
Data gathering	64
Data check (data reduction).....	64
Data upload.....	65
System maintenance	65
5.6 KdUINO (KdUSTICK and KdUMOD).....	66
System description.....	66
System set-up/installation	67
System check.....	69
Field calibration	69
Data gathering	70
Data check	70
Data upload.....	71
System maintenance	71
5.7 FreshWater Watch (FWW)	72
System description.....	72
System set-up/Installation.....	73
Data gathering	74
Data check (quality control)	74
System maintenance and open data access	75
6. Exploitation and Dissemination	76
7. Future activities/recommendations	76
8. References.....	76



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

LIST OF ACRONYMS

Acronym	Definition
A	Ampere
AC	Alternating Current
Ah	Ampere hour
Chl-a	Chlorophyll- <i>a</i>
DC	Direct Current
DLS	Downwelling Light Sensor
DNS	Domain Name System
E_d	Downwelling irradiance
FOV	Field-of-view
FWHM	Full Width at Half Maximum
FWW	FreshWater Watch
GPS	Global Positioning System
GSM	Global System for Mobile communications
GSD	Ground Sampling Distance
HSR	Peak Design Ltd Hyperspectral Radiometer
IDE	Integrated Development Environment
INS	Inertial Navigation System
IP	Internet Protocol
K_d	Diffuse attenuation coefficient
KML	Keyhole Markup Language
LAN	Local Area Network
LED	Light Emitting Diode
LiPo	Lithium Polymer Battery
L_{sky}	Sky radiance
LTE	Long-Term Evolution
L_{up}	Upwelling radiance
PIN	Personal Identification Number
PVC	Polyvinyl Chloride
RGB	Red-Green-Blue
RPAS	Remotely Piloted Aircraft System
SensorML	Sensor Model Language
SIM	Subscriber Identity Module
So-Rad	Solar-tracking radiometry platform
SOS	Sensor Observation Service
SSH	Secure Shell
TSM	Total Suspended Matter
USB	Universal Serial Bus
V	Volt
VDC	Volts Direct Current



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

W	Watt
WAN	Wireless Area Network
ρ_{sky}	Sky reflectance



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

1. Executive Summary

This document constitutes Deliverable 3.2 of the MONOCLE project and defines operational protocols for deployment of new sensors and platforms. Most systems described here are designed to collect radiometric data to characterise irradiance arriving at and leaving the water surface. These systems are essential to build ground networks to support satellite observation calibration and validation. The systems described here range from those delivering low-cost observations, including smartphone extensions and the use of ‘prosumer’ drones with added payload, to reference systems incorporating high-end spectrometers to provide stable measurements from diverse platforms. In addition, sensors and methodologies which complement in situ and remote radiometric observations are included, specifically to monitor nutrients, turbidity and transparency in optically and morphologically complex water bodies, at small spatial scales.

2. Scope

The aim of this report is to provide a set of protocols for the deployment of the MONOCLE systems to ensure best practices before, during and after data collection. After reading these protocols, operators will be able to work with the following MONOCLE sensors/platforms in the field to collect reliable data:

- Peak Design Ltd Hyperspectral Radiometer (**HSR**): intended for permanent mounting situations, providing reference measurements of hyperspectral Global and Diffuse irradiance in the 350 nm – 1050 nm spectral range
- Solar-tracking radiometry platform (**So-Rad**): intended to maintain optimal viewing angles of radiance sensors recording water-leaving reflectance in order to avoid sun glint and platform shading, even from moving platforms (ships and buoys). The system is developed to operate autonomously, with low power consumption, integrating radiance sensors and providing connectivity with the MONOCLE back-end.
- **WISPstation**: using two sets of sensors looking NNW and NNE to collect water leaving reflectance data. On the northern hemisphere it is normally installed looking in a northward direction, providing two optimal viewing geometry moments during the day and a large time window with acceptable viewing geometries that can be accounted for.
- Imaging sensors onboard of Remotely Piloted Aircraft Systems (**RPAS** or **drones**): for the observation of water-leaving reflectance and to derive water quality parameters including Total Suspended Matter (TSM) and chlorophyll-*a* (Chl-*a*) with RGB and multispectral sensors.
- **iSPEX 2**: a smartphone add-on that turns the smartphone camera into a spectropolarimeter. A grating projects a spectrum onto the smartphone camera. This spectrum is modulated by a highly chromatic retarder to include dark bands that contain information on the linear polarisation of the incoming light.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- **KdUINO (KdUSTICK and KdUMOD)**, a Do-It-Yourself moored instrument that measures the diffuse attenuation coefficient (Kd). The purpose is to assess the water transparency, a critical parameter to know the environmental status of water bodies, strongly affected by different water quality related components (such as the presence of phytoplankton, organic matter and sediment concentrations).
- **FreshWater Watch (FWW)** is an integrated and flexible citizen science programme run with a specific focus on water quality monitoring. The programme was designed to explore the effects of river restoration, catchment management practices and land use change on the chemical, biological and optical characteristics of freshwater ecosystems, including lakes, ponds, streams, rivers, canals, and wetlands.

There are additional MONOCLE sensor developments which are not covered in this document, which are pending further development to reached the required technological readiness before optimal deployment protocols can be defined. For further updates and information, the reader is referred to the MONOCLE website section describing the full range of observation methods and learning materials provided for them: https://monocle-h2020.eu/Sensors_and_services

3. Introduction

MONOCLE innovates water quality observation techniques by developing new and enhancing existing sensor technology platforms to lower the cost of acquisition and data collection. To ensure reliable in situ observations in a range of environments and by diverse operators, operational protocols are required. These protocols provide instructions on the set-up of the new sensors and explain new sensing methods which allow high quality data to be collected. By including field calibration guidelines, operational costs of the systems can further be reduced. This document is the first collection of such protocols which will be tested and fine-tuned throughout the MONOCLE field campaigns.

The set of protocols will ultimately guide future users in best-practices for using these systems. Section 4 lists the MONOCLE systems that are discussed. Section 5 focusses on the acquisition and deployment techniques for the different systems. First, a short description of the system is given, followed by guidelines on the set-up, including hardware and software, communication and power requirements. Essential system checks are included to detect possible failures in the set-up phase. Next, in-field calibration tests are described (where already developed) to ensure data quality before the best-practices on data gathering are provided. A checklist is included to verify whether errors occurred during the data gathering, before these data are further distributed and uploaded. A final section describes maintenance efforts of the system, where applicable. Section 6 discusses linked exploitation and dissemination activities, while Section 7 summarises future activities and recommendations.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

4. Overview of MONOCLE systems

Seven MONOCLE sensor systems/platforms developed in the project are considered here. Their main features are summarized in Table 1. The sensor systems are fully described in D4.1 “Performance criteria for field testing” (Riddick et al. 2018) and technological and cost requirements for these sensors are described in D2.1 “Report on analysis of the requirements for MONOCLE sensors including projection of cost-savings and stakeholder feedback”.

Table 1. List of MONOCLE sensors and systems

System	Developer	Priority Type (Accuracy/ Spatial Coverage / Low cost)	Measurement
HSR1	Peak Design Ltd	Accuracy	Global and diffuse spectral irradiance
Solar-tracking radiometry platform (So-Rad)	PML	Accuracy / Spatial coverage	Water-leaving reflectance under optimal viewing angles
WISPstation	Water Insight	Accuracy	Remote sensing reflectance (R_{rs})
Prosumer RPAS drone system	VITO/Sitemark	Accuracy and detailed spatial coverage. Low cost cameras also considered.	Water-leaving reflectance, Total Suspended Matter (TSM) and chlorophyll-a (Chl-a)
iSPEX 2	University of Leiden/DDQ	Spatial coverage at low cost	Aerosol optical thickness (AOT) and remote sensing reflectance (R_{rs})
KdUStick, KdUMod	CSIC	Low cost / Spatial coverage	Light attenuation coefficient (K_d)
FreshWaterWatch	Earthwatch	Spatial coverage (microscale)	Water colour, turbidity and phosphate

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5. Acquisition and deployment protocols

5.1 Peak Design Ltd Hyperspectral Radiometer – HSR1

System description

This instrument is intended for permanent mounting situations and will provide reference measurements of hyperspectral Global & Diffuse irradiance in the 350 nm – 1050 nm spectral range.

System set-up/Installation

The radiometer should be firmly mounted to a horizontal surface or vertical pole or railings using the brackets provided or similar fixings.



Figure 1 Peak Design Ltd Hyperspectral Radiometer – Set-up

In a fixed installation, the radiometer position should be levelled so that the internal bubble-level shows horizontal.

In moving installations (boat or buoy) the position should be as close to horizontal as reasonable. Orientation sensor information will be required (either internal to the instrument or externally) for best results.

Power – the radiometer requires 12 Volts Direct Current (VDC) at up to 1 Ampere (A). A permanent mains or generator-powered supply is ideal. For remote locations, a solar panel & battery can be used. The solar charge controller should be able to communicate with the radiometer and adjust power usage and measurement frequency to the power available.

Communications – ideally a network connection is provided via local network or a GSM / WiFi connection.

System check list

- Does the bubble level show correct horizontal orientation?
- Does the indicator Light Emitting Diode (LED) inside optical dome flash periodically when readings are taken?

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Is the glass dome clean and free of dust, dirt or bird droppings?
- Log in to the instrument via network to access the operating software and set up logging parameters or retrieve data.

Field calibration

The radiometer should be laboratory calibrated every two years.

Data gathering

Once the instrument is operating, data will be stored to the internal storage for more than a year.

Data may be uploaded automatically to an external store or the MONOCLE back-end if this is set in the operating software.

Data may be retrieved by logging in to the radiometer via the network connection and downloading the data files.

Data check

The data can be viewed in the operating software or by standalone app to give an overview of irradiance or other derived values to check for correct operation. Other supporting data (power supply, internal relative humidity, orientation, position etc) can also be viewed.

Data upload

Data may be automatically uploaded to the MONOCLE server if this is enabled in software (feature under development).

System maintenance

Daily / weekly – check for clean dome, horizontal mounting, internal RH (indicator within dome, or remotely via network). Check operation locally (LED flashing) or remotely via network login.

Yearly or as needed. Replace internal desiccant pack.

The radiometer should be calibrated in a laboratory every two years. An operational calibration check may be developed during the project.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.2 Solar-tracking radiometer platform (So-Rad)

System description

The purpose of the system is to maintain optimal viewing angles of radiance sensors recording water-leaving reflectance to avoid sun glint and platform shading, even from moving platforms (ships, buoys). The system is developed to operate autonomously, with low power consumption (15W), integrating existing radiometers and providing connectivity with the MONOCLE back-end.

The system combines off-the-shelf and purpose-built components. Two radiometers are mounted on a bracket which controls the horizontal (azimuth) sensor viewing angle, designed for this specific purpose. The system is controlled from a single deck box (Figure 2). The open source software has a modular design. Currently it supports TriOS Ramses spectroradiometers (one irradiance and two radiance sensors), which can be extended to other sensors for which an application programming interface is available. Details are given in the following sections.



Figure 2 The So-Rad system mounted on a car ferry on Lake Balaton in June – July 2019, showing the two radiance sensors on a rotating enclosure (top) and the integrated controller and power supply box (bottom).

Hardware components

The system consists of the following physical units (referring to numbered items in Figure 3):

1. Control unit: this includes the controller for the motor stack, Long-Term Evolution (LTE) modem, power supplies (24/12/5V), solid-state relays, fuses, a Raspberry Pi to control the system, tilt/pitch/ro. The current prototype has the option to choose from mains power (AC 220-240V) with battery backup for sensors and Raspberry Pi, or a solar energy fed power setup (DC 12V).

2-3. Rotating sensor platform: an enclosure around a stack of geared stepper motor, encoder and brake, which is positioned over the side of a ship using stainless steel mounts, ideally with a wide unobstructed view of the sea, such as the bow of a ship. Because every platform is different, only the part to support the motor enclosure (3) is provided with the So-Rad. A platform-specific bracket

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

should be made to specifications and to match the mating plate of this support. A single cable conduit (4) connects the control unit and the motor platform, which does no include sensor cables (5).

6. Global Positioning System (GPS) units: two GPS receivers positioned along the ship bow-stern axis, as far apart as cabling allows (recommended minimum 2-3 m) and ideally observing the same portion of unobstructed sky (GPS signals ‘bounce’ on metal structures which increases positioning uncertainty).

Optional: Solar power supply: a battery and charging circuitry box, and a solar panel. A 100 W panel and 100 Ah Lithium battery suffice to keep the system running over several overcast days. Power consumption of the whole system is approximately 15W. If it is found that the system drains the battery faster than it recharges, additional solar panels can be added. Li-on batteries form the main expense of this power supply option but are recommended over lead-acid batteries. The default configuration of the control unit operates on a 220-240 V power supply (7).

A complete guide to the construction and configuration of the So-Rad is available (Wright and Simis, 2020). All elements of the So-Rad (hardware and software) are published under a Creative Commons Attribution-Non Commercial license.

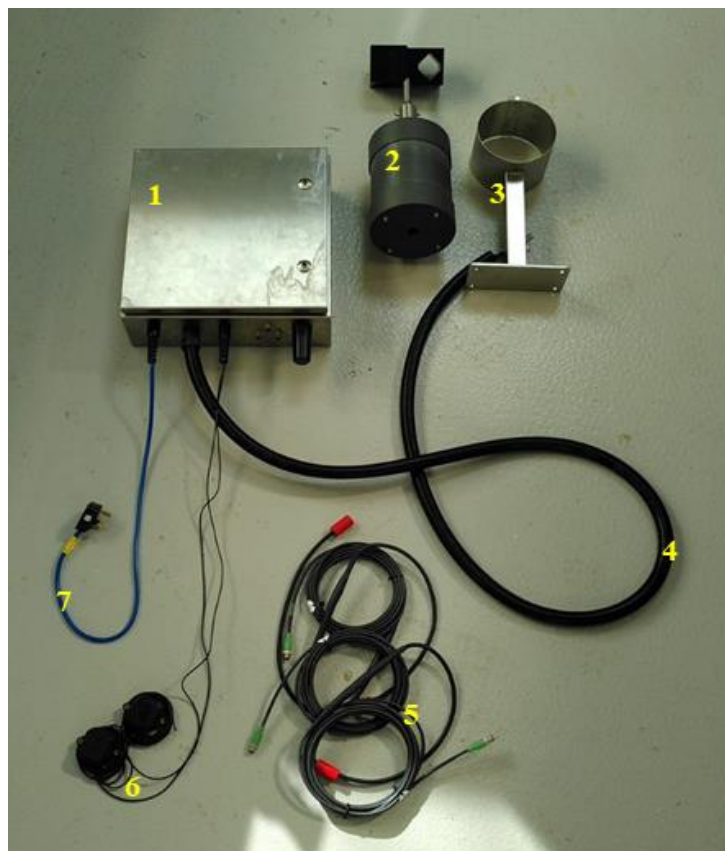


Figure 3 So-Rad unit with (1) Control unit, (2) motor enclosure, (3) mounting bracket, (4) motor cables, (5) sensor cables, (6) GPS receivers and (7) AC mains power cord

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Software / data interfaces

The controller software is implemented in Python and is published open-source under a non-commercial license (<https://github.com/monocle-h2020/so-rad>). Figure 4 provides a functional description of the various software components used to control the hardware, including:

User configuration files: provide metadata about the deployment platform and data ownership, connection properties for all sensors, deployment limits (e.g. to radial movement).

Main application: interface calling and instructing all sub-processes in parallel threads, as well as monitoring internet connectivity and solid-state relays to provide power to system components. The main application collects all required system state information to determine whether measurements should be made. The main application calls upon:

- *Gps_manager*: connects to two GPS sensors to provide accurate heading information in addition to position and time information
- *Sensor_manager*: connects to two radiance sensors and one irradiance sensor, triggering new measurements at user-configurable intervals when minimum measurement conditions are met.
- *Motor_manager*: calculates optimal heading of the motor depending on ship heading, longitude and time (from *Gps_manager*) as well as platform definitions (from user configuration, e.g. where is the sensor mounted on ship) and current motor viewing angle.
- *Log_db*: handles all logging and requests to/from a local database, which acts as data buffer.
- *Battery_manager* (optional): when system operates on battery power and the battery or (solar) charger provides information on charge and load status, this information is logged and generates a status flag, indicating stable power supply (normal operation), low power (reduce consumption) or critical power (idle mode).

The system provides the following interfaces for operators to interact with the system:

- **Automated Secure Shell** (SSH) callback which periodically tries to connect to a central MONOCLE server or external dynamic Domain Name System (DNS), providing a reverse SSH tunnel to allow remote control and troubleshooting of the system, when an internet connection is available.
- A **micro web service** providing a status page, system logs and further routes to set operating mode (e.g. automated/manual/calibration – still under development), which can be reached by a local user connected to the router contained in the control box (cabled or WiFi), or by a remote user over SSH.
- An automated, efficient **data transfer mechanism** which packages observations and metadata, queries a remote database and uploads new observations. At the same time, data are buffered at the platform itself.
- A periodic check for updates to user configurations provided at a user-configured URL.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

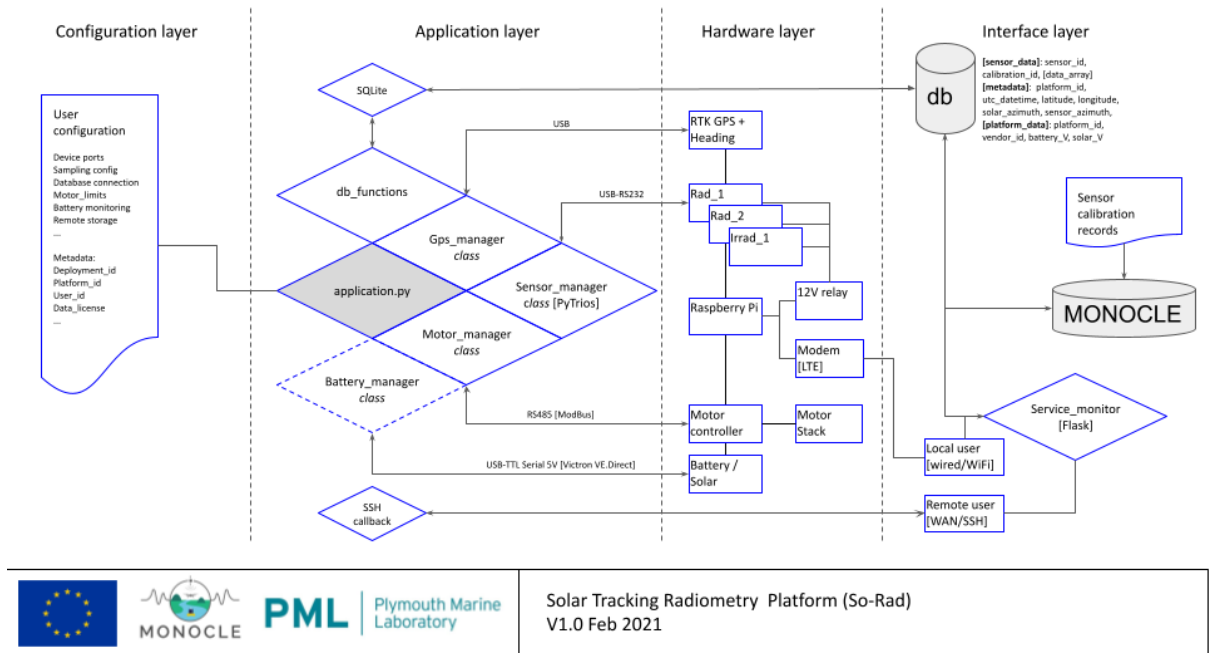


Figure 4 So-Rad system flow-chart

System set-up/Installation

Installing the system components

The following instructions assume installation on a ship.

Tools required: Set of Allen keys, spanners and cable ties

1. Install the motor platform near the forward bow or along a front side of the ship, thus providing the largest unobstructed view of the water surface while avoiding the wake of the ship.
2. Attach the radiance sensors to the motor platform. The sensor brackets point at 40 degrees forward angles (i.e. from vertical), one radiance sensor is to point up and the other to the water. Align the 'home' position of the motor (marked on the motor housing) with the ship bow-stern axis so that sensors point in the forward direction (away from the ship) when the motor is in the home position. A rotational offset to the home position can also be configured in the software but the offset must then be recorded on installation. Secure cables to the ship to ensure free rotational movement of the sensors, but tight enough to prevent cables catching on moving parts. The default motor for the So-Rad has a low torque (0.3 Nm) to prevent any possibility of damage to cables while resisting e.g. wind. However, it is possible to select a motor with higher torque (up to 3 Nm, geared).
3. Install the irradiance sensor at a high point on the ship where it is free from shading by any ship structure. This sensor must point straight up. The sensors and their cabling are interchangeable: when calculating reflectance, it is automatically assumed that the lowest signal corresponds to water-leaving radiance, the highest signal to downwelling irradiance and the intermediate signal is the sky radiance.
4. Mount the control unit and optional solar / battery box vertically so that all cable connections are at the bottom. The Tilt sensor of the system is included in the control unit, so this must be installed

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

level. Additionally it is recommend to inspect the tilt reported by the unit after installation, making any required mounting adjustments to accurately record tilt. Recording data with tilt > 5° is not recommended.

5. Mount the GPS receivers parallel to the bow-stern axis of the ship. The GPS receivers marked 'FRONT' should be positioned several meters ahead of the sensor marked 'REAR'. It is recommended that the sensors have an unobstructed view of the sky.

6. Mount any additional items, such as solar panel and communications antenna, at suitable locations.

7. Connect all data / communication cables (but not power cables).

8. Open the controller box (only in dry conditions) and ensure power connectors are switched off.

9. Connect power cables in the following order, as applicable: connect controller box to mains or battery box. If using solar, connect solar panel to battery box last. Always be aware that solar panels hold a voltage when exposed to light.

10. Secure all loose cables to ship structure using cable ties.

Powering on the system

Refer to Figure 5 for numbered items.



Figure 5 Control unit configured for mains power. Numbered items are described in the text.

Only open the controller box when it is safe to do so. Before connecting to mains or battery power, switch the fused terminal switch (1) to OFF. Alternatively, fit a switch on the power supply line feeding power to the control unit.

Mains power operation:

1. Connect mains power plug to a suitable electric outlet.
2. Switch socket 1 ON.
3. Ensure that indicator lights on the DC 24V (2), DC 12V (3) and DC 5V (4) supplies, motor controller (5), Raspberry Pi (6) and USB hub (7) are all ON. Within minutes, the solid-state

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

relay (8) will switch on and the motor should move first to its home position and then the optimal measurement position (if measurement conditions are met).

4. Close and lock the controller enclosure.

Communication components

Install a suitable SIM card in the modem. Use a laptop to set up the SIM Personal Identification Number (PIN) and internet access point by connecting to a free Ethernet port (the port marked Wireless Area Network (WAN) is pre-configured as Local Area Network (LAN) port 2). Open a browser and navigate to 192.168.0.1 and provide the name and password written on the modem.

System check

Normally, if all systems are connected properly, soon after the Raspberry Pi has finished powering up it will switch on the sensor relay (green light) and some adjustment of the sensor viewing angle can be noted. It may take a few minutes for the GPS sensors to obtain a position fix, before the systems starts its operation.

- If all systems appear to work normally, it is possible to check data flow by connecting to the Raspberry Pi from a laptop, phone or tablet either over the local WiFi, cabled connection the modem, or via the internet (depending on whether remote configuration has been set – details on this configuration are provided in the Build Guide). The IP address for locally connecting to the system is indicated on the inside of the control unit. If remote monitoring has been enabled, a unique URL will have been provided. The status page should show which sensors are connected.

- Verify that the 24V, 12V and 5V power supplies show a green ‘DC OK’ light. If none show a light, there is a problem with power supply to or within the controller box. Verify that the correct power source has been chosen on the rotary connector and that the respective switchable fuse is ON. If some are on while others are not, there is an electrical problem that should be handled by a qualified engineer.

- If a motor failure is suspected because movement was blocked (e.g. a cable was caught, or someone was cleaning the sensors), first check the system logs which should identify a motor alarm. If a motor alarm is present, the motor controller will also show a blinking red light instead of green. First ensure that the sensor cables are not blocking motor movement and that the system is still mounted as intended. Never adjust any of the power/brake/encoder cables that connect the motor controller to the motor, unless the system is powered down first. Motor faults are rare and blocked movement will normally be the reason for the alarm. Once the underlying issue has been corrected, power-cycle the system and operation should resume normally.

- If the problem does not appear to be related to blocked movement, then to identify the motor alarm a PC can be connected over the Universal Serial Bus (USB) port of the motor controller, then using the MEXE02 software the alarm can be further identified. A motor alarm will also show in the system logs that can be viewed locally (WiFi/cable) or remotely (if enabled and connected). A motor issue should be investigated on-site, to prevent issues with cables getting caught from recurring. Once issues have been resolved follow the above steps to power cycle the system. Alternatively, a remote reset is possible using the scripts available in the So-Rad system tests folder (/home/pi/sorad-code/bin/tests) to detect and reset motor alarms.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Field calibration

Procedures to support field calibration are still under development. We refer to Deliverable 6.2 for a methodology to detect drift of the downwelling irradiance sensor, achieved by comparison against modelled sky irradiance under clear-sky conditions. Clear-sky conditions will be determined by inspecting the ratio of sky radiance over downwelling irradiance, which under clear sky conditions should resemble the spectral dependence of Rayleigh scatter (Groetsch et al. 2018). This approach is expected to identify major fouling, and possibly long-term drift.

Prior to long deployments (a whole season or longer) we recommend that the sensors are calibrated in a dedicated laboratory. This way, data will be valid for satellite calibration and validation.

Intermediary, relative calibration is possible by recording the radiance of a diffuse reflectance target and downwelling irradiance simultaneously with all sensors. This allows sensor inter-calibration. While the reference target does not need to be of high calibre (such as e.g. spectralon), it does need to be characterized with the same set of sensors before initial sensor deployment, and then kept clean and stable. The field calibration should be carried out under a clear sky with sun at high elevation. Under these conditions, the irradiance sensor will capture the full spectrum of sunlight arriving at the reflectance panel. The radiance sensors pointed at this panel should measure a signal equal to $1/\pi$ of the irradiance. These readings can then be used to produce a secondary calibration spectrum for each radiance sensor. The secondary calibration is applied in data post-processing. Automation of this procedure using the So-Rad software and data backend is still underway. It is noted that secondary intercalibration of the sensors is a good way to prolong the interval between laboratory calibrations and will yield accurate Reflectance, since this is a relative measurement between the sensor signals. Over time, the sensors are expected to degrade and therefore their absolute values cannot be used without occasional laboratory re-calibration.

Data gathering

The So-Rad system will **automatically** prevent data collection if suitable conditions are not met. These settings and threshold criteria are user-configurable through the configuration file as indicated in **bold**, with recommended settings as shown below:

- The regular sampling **interval** is set to 10-15 seconds when using TriOS G1 sensors
- Sensor viewing azimuth angle should be **> 90°**, **< 145°** and as near as possible to 135° away from the solar azimuth.
- The GPS receiver should acquire a 3D fix and the latest information on latitude, longitude and heading may not be more than **2** seconds old.
- Solar elevation must be **> 30°**.
- The sensor viewing angle is within **clockwise / counter-clockwise limits** defined by its position on the ship (to prevent looking at the ship itself) which must be defined in the user configuration file. The values are given in degrees relative to the ship bow-stern axis.
- The irradiance sensor can optionally be configured to continue measurements, even when conditions suitable for reflectance measurements are not met, to support e.g. primary production studies. The **interval** (in seconds) for downwelling irradiance (E_d) measurements outside the normal measurement interval can be specified.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Sensor **timeout interval** (in seconds): if data are not returned within this interval from a measurement trigger, sensor connectivity may have been lost or an incomplete measurement returned, or serial data became corrupted. . This setting is sensor specific. For TriOS sensors using the PyTrios protocol it is set to 12 seconds.
- Number of **timeouts allowed (3)**: if the number of consecutive timeouts is exceeded, power to the sensor is cycled to bring it back online.

All user configurations are stored in two configuration files in the sorad-code folder on the Raspberry Pi. The file config.ini holds default settings. This file will be over-written when a firmware update is applied. The file config-local.ini is used to override any of the default settings, and it is recommended to make changes only to this file, and to backup its contents.

A procedure to periodically update the config-local.ini file from a remote location, is being implemented. This will allow the remote operator to change the sampling schedule of the So-Rad. When the platform is connected to the internet, new settings will be downloaded to override the system defaults. Only non-critical settings can be specified in this manner. A usage example is where the operator keeps a configuration file for each So-Rad platform in secure cloud storage (e.g. Dropbox). The remote link to the file is added to the config-local.ini settings along with a specified interval to check for updates. In another usage scenario, updates to the sampling schedule can be automated, by updating the remote configuration file held in cloud storage, e.g. to follow the schedule of satellite overpasses.

Data check

The first check of normal data throughput is to see whether all sensors return data. When viewing conditions are suitable for reflectance measurements, these should come through in sets of three (one record per sensor).

Further checks require calibration data to be applied to the raw data, and are out of scope of this document. Data anomalies and processing algorithms are discussed in D6.1.

Data upload

Data upload to the MONOCLE back-end can take place through several mechanisms depending on system connectivity and downstream data processing needs. In MONOCLE, the use of the SOS data standard has been investigated but this is considered suboptimal for the complex set of data types associated with a single observation of the So-Rad. Alternative ‘smart’ data transfer mechanisms are being investigated whilst FTP or file synchronization services (e.g. Dropbox, Owncloud) can be set up independently from the So-Rad control software. Additionally, data are stored on the Raspberry Pi SD card in a local sqlite database, which can be downloaded in its entirety over a remote connection.

System maintenance

The system is expected to be maintenance free apart from sensor care (cleaning with fresh water) and absolute calibration of the radiometers as recommended by the sensor manufacturer or when drift is detected (WP6 efforts). Solar power supplies should be cleaned regularly. In addition cabling and mountings should be checked regularly (at least annually) for degradation or corrosion. Replacement

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

of (optional) batteries will depend on usage and charging patterns and these should be monitored over time.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.3 WISPstation

System description

Regular monitoring of water quality is an obligation in several directives of the European Union (Water Framework Directive, Bathing water directive, Marine Strategy, etc) and important in many local, regional and national monitoring frameworks. With climate change and population increase, concerns are raised that clean water may become scarcer. Erratic precipitation and global warming may lead to serious water quantity and quality problems. Processes like eutrophication, turbidification and proliferation of cyanobacterial blooms can be witnessed more frequently and on a larger scale than ever before. Due to the dynamic nature of water movement and quality in the areas where the dependency on this natural resource is the highest (coastal areas, inland waters) frequent monitoring is a challenge. To understand these processes on a global scale, innovative monitoring techniques are proposed based on e.g. optical remote sensing (Dekker and Pinnel 2018). Since satellite images have still infrequent temporal coverage (obstruction by clouds, overpass restrictions), additional monitoring strategies are required. Because the satellite derived reflectance- and water quality products need calibration, it is important to have match-up reflectance data collected at the surface. Based on the experience with the handheld WISP-3 system (Hommersom et al. 2012) it was clear that the optical measurement techniques imbedded in the WISP-3 system make it suitable for both satellite validation studies and direct in situ estimates of water quality parameters. Many (potential) clients have additionally requested a fixed position instrument because that would allow to measure semi-continuously without going out in the field. Water Insight has developed such a fixed position autonomous optical measurement device, the “WISPstation”.

Characteristics of the WISPstation instrument

Several approaches to viewing geometry and system design for above water radiometric systems have been proposed:

- a) The sun-following design with one-radiometer (Seaprism, see Zibordi et al. 2009), or with 3 radiometers (Dalec, see Brando et al. 2016, or the So-Rad described in this document)
- b) Single-viewing angle, dual radiometer system with the upwelling radiance (L_{up}) sensor under water (Lee et al. 2010)
- c) Multiple viewing angles system (Wernand 2002, Tilstone et al. 2002)

Basis for designs a) and c) are the considerations by Mobley (1999), namely azimuth angle is optimal around 138 degrees from the sun, L_{up} angle is around 42 degrees from the nadir and sky radiance (L_{sky}) angle is around 42 degrees from the zenith. With varying geometry, Mobley proposes a table of coefficients to account for surface reflections at various wind speeds and solar position.

The WISPstation is based on a modification of the Wernand design (c) using two sets of sensors looking NNW and NNE instead of NW and NE. It should preferably be installed looking in a northward direction (on the Northern hemisphere) providing two optimal viewing geometry moments during the day and a large time window with acceptable viewing geometries that can be accounted for. The advantage of a fixed system with two viewing directions is that there are no moving parts, robots etc. which makes the system less costly, better to maintain and less prone to malfunctions.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

In total the WISPstation features 8 channels:

- 2 Radiance channels collecting L_{up} and L_{sky} in the NNW direction
- 2 Radiance channels collecting L_{up} and L_{sky} in the NNE direction
- 2 Irradiance channels
- 1 unexposed dark radiance channel for evaluation of radiance channel degradation
- 1 unexposed dark irradiance channel for evaluation of the degradation of irradiance channels

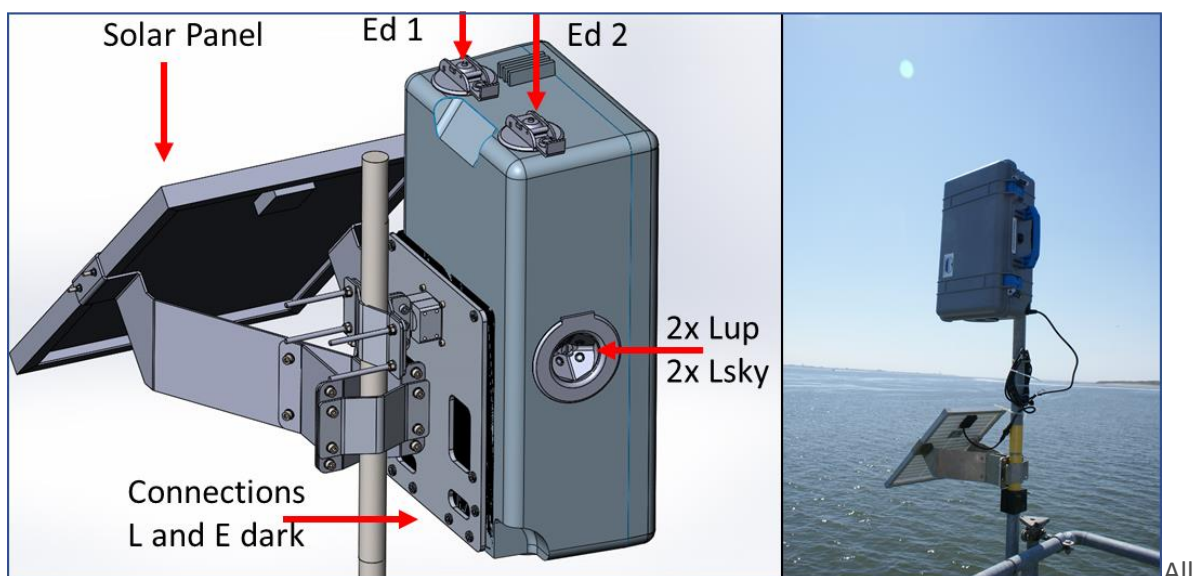


Figure 6 Layout and installation of a WISPstation

Channels are connected to the central spectrometer by means of optical fibres and an optical multiplexer. The advantage of this design is, amongst others, that any variability or degradation of the sensitivity of the spectrometer is compensated in the calculation of remote sensing reflectance. A regular measurement cycle where each channel is measured 10 times at an optimal integration time takes usually less than 1 minute depending on ambient light conditions. The system is calibrated relative to a reference instrument. The reference instrument is calibrated in a certified laboratory using a lamp and integrating sphere with National Institute of Standards and Technology (NIST) traceable calibrations.

The WISPstation is water-tight and built into a highly climate resistant case. Temperature of the sensor and humidity in the case is registered along with every measurement. Data are transmitted to the database (“WISPcloud”) autonomously through a cellular connection. The instrument can be remotely accessed and e.g. updated or configured to a specific time interval or measurement frequency. It is autonomously powered by a solar panel and internal large battery. The instrument is built into a very sturdy case with the dimensions: 55 x 38 x 23 cm and weighs around 13 kg.

Currently the WISPstation is built around the Avantes Mini mk-1 spectrometer with a maximum wavelength range between 220 and 1100 nm. The grating has 300 lines per mm with a blaze of 300 nm. Together with a slit of 100 μ m this leads to a spectral resolution (Full Width Half Maximum

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

(FWHM)) of 4.65 nm. Stray light is reported to be lower than 0.2%. The WISPstation spectral characteristics are to some extent configurable. The Avantes Mini is a rugged spectrometer designed for use outside of laboratories. Serial production by assembly robots warranty very small differences between instruments. While the standard measurement frequency is set to once per 15 minutes, it can be increased to once per two minutes if required, e.g. in intervals around satellite overpasses.

A scalable Postgres database (WISPcloud) is available to autonomously receive and store all measurements, to perform quality control, to apply water quality algorithms and to serve data requests directly to customers through an advanced API. Internal quality control procedures are increasingly being put into place to identify and flag sub-optimal measurements.

Skylight/glint correction is currently handled in a basic manner (fixed sky reflectance, $\rho_{sky} = 0.028$), the results of research into advanced options for glint correction (Groetsch et al. 2018) will be implemented next.

System set-up/Installation

Important considerations

Before proceeding with installation, the following very important conditions must be considered:

- 1) The side with the round black lens holder should face exactly North and have a free view at the water
- 2) The solar panel at the other side should face southwards
- 3) There should preferably be nothing above the instrument, otherwise the measurement of downward irradiance measurement is affected
- 4) The pole should be round and maximally 10 cm diameter. We do not know what the minimum diameter is but e.g. a sturdy 4-6 cm steel pipe should be ok
- 5) The instrument should be able to find the 3G network
- 6) The location should not have bottom visibility
- 7) The upward looking sky sensors should only see sky, no buildings or trees etc.
- 8) The upward looking Ed sensors should have a clear view 360 degrees around the instrument with nothing higher than the top of the case for at least 10 m around the instrument (ideally nothing at all).
- 9) The instrument should not be installed at a location where it would see artificial light during daylight time: (lamp posts, car lights, advertisements etc.) either directly or reflected from the water surface

Figure 7 shows the completed installation.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

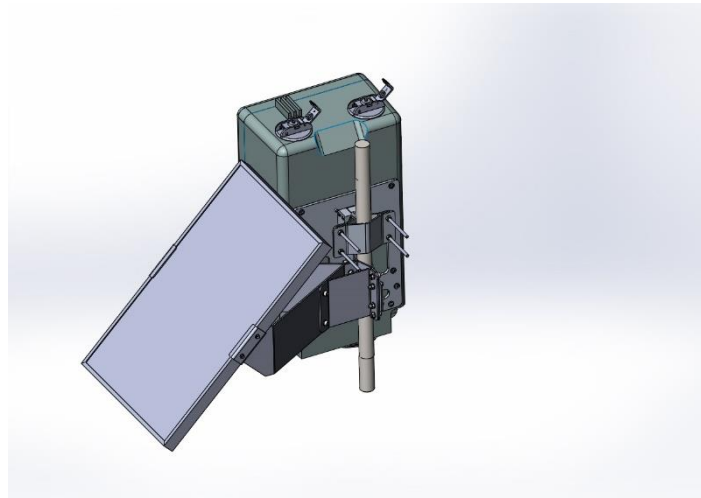


Figure 7 WISPstation set-up

Materials needed:

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
	1 Wr1-KP04-Tussenstuk-V1		1
	2 Paal		2
	3 Wr1-KP06-Gebogen plaat buis-v1		2
	4 Wr1-KP01-Achterplaat-V1		1
	5 Wr1-KP03-Klemstuk2-V1		1
	6 Wr1-KP02-Klemstuk1-V1		1
	7 Din 439 B M4 Lagemoer		4
	8 binnenkantzeskant_Din912_M4	Din 912 M4 x 14mm	4
	9 binnenkantzeskant_Din912_M4	Din912 M4 x 24	4
	10 binnenkantzeskant_Din912_M6	Din912 M6 x 20mm	3
	11 Din985 M6 (met borging)	Din985 M6 (met borging)	21
	12 Wr1-KP05-Buisdeel-V2		2
	13 Wr1-KP07-koffersimul-V1		1
	14 binnenkantzeskant_Din912_M6	Din912 M6 x 90mm	4
	15 Ring Din125A	Din 125A M6	52
	16 Pelicase-schroef		10
	17 zonnepaneel		1
	18 Wr1-KP08-zonklem-V1		1
	19 Wr1-KP09-zonklem-V1		1
	20 binnenkantzeskant_Din912_M6	Din912 M6 x 18mm	10
	21 Wr1-KP10-verstijvingsplaat-V1		2
	22 binnenkantzeskant_Din912_M6	Din912 M6 x 25	4
	23 binnenkantzeskant_Din912_M4	DIN 912 M4 x 12mm	4
	24 Ring Din125A	Din 125A M4	4
	25 Din985 Moer metborging	Din985 M4(metborging)	4

Tools needed for assembly

1. Set of Imbussleutels (Hex keys)
2. Set of Steeksleutels (Fork spanners)
3. Bundel of Typraps for cable of the solar panel.

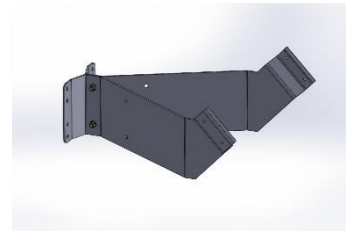
Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Integration steps

Step 1: Bolt the two plates together.

Material:

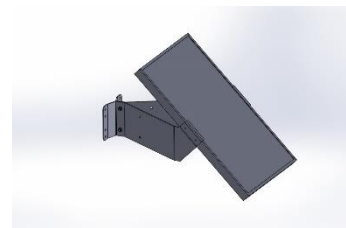
- 2x M6x 18 mm
- 4x Washer M6
- 2x nut M6



Step 2: Bolt the solar panel to two plates. The Plates are still flexible so you can pull them a little apart and put the solar panel in between.

Material:

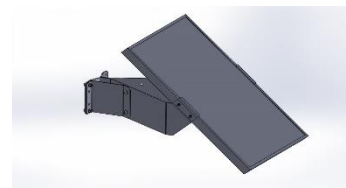
- 4x M4x 20 mm
- 4x Washer M4
- 4x nut M4



Step 3: Bolt the stiffener plates to the assembly

Material:

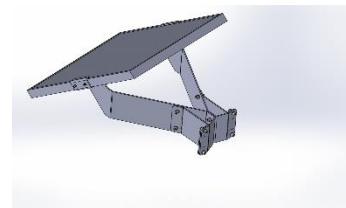
- 4x M6x 18 mm
- 8x Washer M6
- 4x nut M6



Step 4: Bolt the second stiffener plates to the assembly

Material:

- 4x M6x 18 mm
- 8x Washer M6
- 4x nut M6

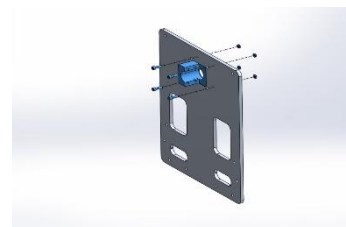


The solar panel part is ready for mounting to the pole. But first we assemble the parts to the pelicase.

Step 5: Take the backplate and bolt the aluminium part.

Material:

- 4x M4x 20 mm
- 4x nut M4

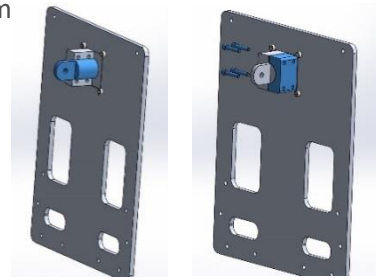


Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Step 6: Insert the stainless steel part into the assembly. It slides in from the backside. Then bolt the Klempart2 to secure the part

Material:

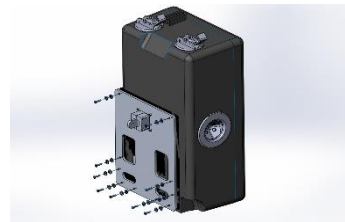
- 4x M4x 20 mm



Step 7: Bolt the backplate to the pelicase. Make sure you use two washers per screw otherwise you can penetrate the pelicase.

Material:

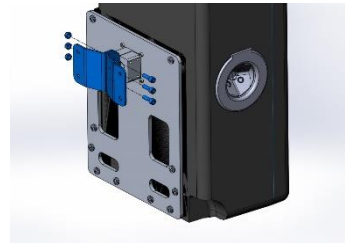
- 10x pelicase screws
- 20x Washer M6



Step 8: Bolt the stiffener plates to the assembly.

Material:

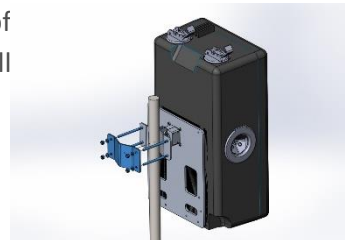
- 3x M6x 20 mm
- 3 x nut M6



Step 9 :Bolt the pelicase to the pole first. Depending on the pole check of the screws are the right length. Poles between 30 mm and 100 mm will work with this mounting system.

Material:

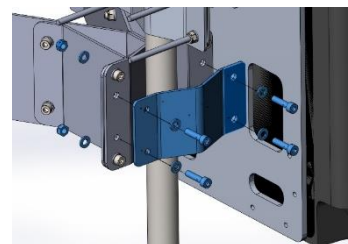
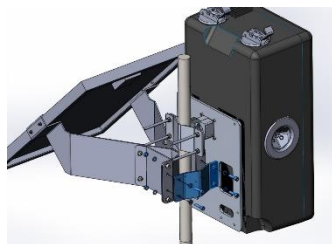
- 4x M6x 90 mm
- 4x Washer M6
- 4x nut M6



Step 10: Bolt the solar panel assembly to the pole. Keep in mind to keep it to the right side of the pelicase and do not obstruct any lenses.

Material:

- 4x M6x 90 mm
- 4x Washer M6
- 4x nut M6



Step 11 :Connect the solar panel to the connector on the pelicase and startup the electronics.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

System check

- 1) The lens holder should be facing North: to check with a compass, caps should have been removed from the lens holder and the Ed sensors.
- 2) The system should be level: to be checked with a water level on the ledge of the lens holder
- 3) It is preferred to turn on the system maximally one day before going into the field. Water Insight will connect to the system to see if log-data are coming in. The only measure a client can do is open the lid on the bottom side of the instrument; insert the key and turn it 90 degrees; take out the key and screw the lid back on (5 bolts). WI has the possibility to switch on a led, visible when the lid is off, with some colour coded messages to indicate the state of the system when there is a problem. The client has the possibility to disconnect the system and fire it up again by turning the key, but this should only be done after consulting Water Insight.

Field calibration

Currently we do not provide a means to do field calibration of the instrument since it comes calibrated to a NIST traceable standard. An approach could be to perform a small series of consecutive WISP-3 measurements to assess deviations from the factory calibration.

Data gathering

The WISPstation data are automatically uploaded to our back-end system: WISPcloud. The only criteria to ensure good data quality is to have a proper orientation of the instrument.

Data check

The instrument performs and records a number of quality checks. Internal temperature and humidity are recorded, together with Battery voltage, power use by the system and integration time per channel. The instrument will not measure at temperatures below a set threshold. After conversion to json datafile, the firmware checks if the package is complete and sends it to the back-end.

Further measurement quality checks are performed automatically by the back-end software. At WI we run a dashboard that instantly shows the measurements and what quality flags have been applied. This software could be made available to clients in the long run to check the data on a portable device in the field.

Recently functionality was added to read the status of the power supply unit over Bluetooth on a mobile phone app.

Data upload

The WISPstation automatically uploads the data to the back-end software directly after the measurement. If 4G connection is momentarily lost, the package is stored on the system until the connection is restored. If this does not happen during the calendar day, the data is stored on the system to be retrieved by remote connection or when back at Water Insight.

System maintenance

Water Insight can remotely login to the system to make changes to firmware or measurement schedule.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

The instrument should be checked regular if the orientation has not changed. The E_d sensors on top of the instrument benefit from regular cleaning, but the frequency depends on the weather: rain cleans the E_d sensors usually sufficiently. In dry spells the E_d sensors should be cleaned maybe once per month, depending on the opportunities to visit the instrument.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.4 Remotely Piloted Aircraft Systems – RPAS

System description

The Prosumer RPAS systems comprise imaging sensors on board drones for the observation of water-leaving reflectance and water quality parameters including Total Suspended Matter (TSM) and chlorophyll-*a* (Chl-*a*). In this document, we will discuss two types of sensors/platforms. First, we will give general instructions for using commonly used drones (DJI Phantom 4 pro) in their standard configuration. Secondly, we will look into a specific case where a multispectral camera is mounted under the DJI Phantom 4 pro. Both are depicted in Figure 8.



Figure 8 Prosumer drone system: (l) the default DJI Phantom 4 pro, (r) DJI Phantom 4 pro with multispectral camera MicaSense RedEdge-M mounted underneath.

System set-up/Installation

Hardware

Default DJI PH4pro

- DJI PH4Pro + batteries (charged)
- DJI battery charger
- DJI box: remote controller + propellers
- iPad (apps installed) + cable
- PC with Chrome browser + charger
- Ethernet cable (5m cable is advised)
- SD cards empty
- SD mini to SD adapter

DJI PH4pro + MicaSense RedEdge-M

- MicaSense RedEdge-M camera + integration kit (Strackx, 2019) + Wifi dongle

Check components

- Light sensor + IMU + GPS receiver on pole
- Battery mount
- Camera mount + offset mount + screws



Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Battery cable
- Elastics
- Tools for integration: cutting pliers; imbus 2.5mm + 4mm
- Straps
- Lens cleaning tissues
- 2x camera battery pack
- Battery pack charging cable + 220V adapter

In the field

- GCP radiometric + fixation pins + hammer
- MicaSense reference panel (in case of MicaSense integration)
- Compass
- Platform for take off

Installation

Installation MicaSense RedEdge under DJI PH4 pro

1. Remove gimbal transport supports.
2. Click the GPS pole onto the right leg of the DJI. Make sure the arrow points forward and that the support clip is at the correct position with regards to the DJI body. Use two elastic bands to strengthen the connection of the GPS pole. During attachment, make sure you don't cover any of the DJI sensors and that the elastics are nicely positioned.
3. Mount the camera brace under the drone by sliding the brace into the frame. Apply two straps to fix the brace to the landing gear.
4. Install the battery support on the landing gear of the DJI PH4 pro and apply four straps to fix the brace to the landing gear.
5. Install the camera: first remove the Wifi dongle of the camera, mount the camera to the vibration damping using the 4 screws. Slide the camera onto the camera brace under the drone till it clicks in position.
6. Make an ethernet connection and secure the cable with a strap.
7. Install the battery in the battery support compartment, plugin the power connector and SECURE the battery. Verify that the battery cannot slide out of the mount.
8. Check the result



Figure 9 Final result of the integration of the MicaSense RedEdge-M camera under DJI Phantom 4 pro drone platform

Documentation/Permits

Check the local drone regulation to find out which documents must be in place before setting up a drone flight, and which restrictions you have to follow. A non-exhaustive list of important documents:

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Operational drone manual
- Certificate of conformance, if applicable
- Pilot licence
- Pilot insurance
- Drone insurance
- Permission from land owners
- Risk assessment
- Check flight restrictions: flight height, range

System check

DJI PH4pro check

- SD card DJI empty or enough space available
- Battery charged

MicaSense integration on DJI solid

- Check pole mount: strap present, 2 elastics present, GPS plate secure, cables secure, GPS solid, DLS solid, stability left/right
- Check battery mount: 4 straps present, battery inserted, battery strap present
- Check camera mount: screws, shock absorbers + 4 straps, slider secure click, camera mount brace solid + 2 straps
- No loose cabling
- Propellers can rotate freely
- Check RGB camera gimbal move freely
- Check Centre of Gravity (props removed, flight battery installed, DJI power down, full camera system installed, camera battery installed, camera unpowered)
- Check camera SD card: empty and installed
- Check WIFI dongle removed
- Check camera lenses clean
- Battery cable secure
- Cable camera to DLS connected
- Cable camera to battery: present but still disconnected
- Connect ethernet cable between camera and laptop
- Connect camera power cable
- Press the camera button shortly to power the camera and wait one minute
- Wait till camera LED flashes green or yellow
- Check camera battery voltage indicator: if only one LED remaining, consider changing the camera battery
- Open Chrome browser and connect to camera and select the HOME tab
- SD card MicaSense empty
- Wait for GPS fix (GPS sats : GREEN ; GPS time correct)
- Camera LED should be flashing green

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

MicaSense camera status

- Tab HOME
 - Storage (= SD card space) : GREEN
 - GPS Sats : GREEN : nr of satellites (≥ 5)
 - DLS Status : GREEN : connected
 - Time : correct time GPS displayed (UTC ; mind summer time)
 - Location : displayed position is correct and stable
 - Altitude : correct : about 0m AGL and stable
 - Speed : correct : about 0m/s and stable
 - Heading (=nose heading) : correct : 0 = NORTH, 90 = EAST ; ...
- Check/modify the camera settings
 - timer + 1 sec, GPS status, DLS status, integration time, all bands enabled, 16bitTIFF
- Disconnect ethernet cable

Field calibration

GPS compass reading

- Check DJI compass reading when facing north: should be 0°
- Use real compass if necessary
- Bring the drone just above the water level and take two picture. This to know the altitude of the water surface in terms of drone GPS.

MicaSense calibration

- Take two images of the MicaSense calibration panel before and after each flight! Use the capture button or camera button to take image !
- The MicaSense calibration panel should be placed flat on the ground, away from any objects to avoid contamination from the surroundings and avoid shadow on the panel. Stand in front of the panel with the sun at your back. Then take a large step to the left or to the right.
- Hold the aircraft at chest level and make sure that the camera is looking nadir (perpendicular to the calibration panel). The panel should cover approximately half of the image.
- These calibration guidelines are also included with the MicaSense calibration panel box.

Downwelling Light Sensor calibration

- Downwelling Light Sensor (DLS) magnetometer calibration is required. Ensure that the light sensor has full view of the sun. Do not cover the light sensor while taking a panel capture.

Reference spectral data

- Put two (or more) spectral reference panels in the flight area (either on shore or on a boat). The albedo of these panels should be around 12%, when obtaining water quality information. When possible, measure the location of these panels with a GPS. This will help in the post-processing steps of the drone data.
- Overfly the panels at least at the beginning and ending of each flight. Although this is sufficient under homogenous sky conditions (clear sky or fully overcast), more overpasses are needed when patchy clouded.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

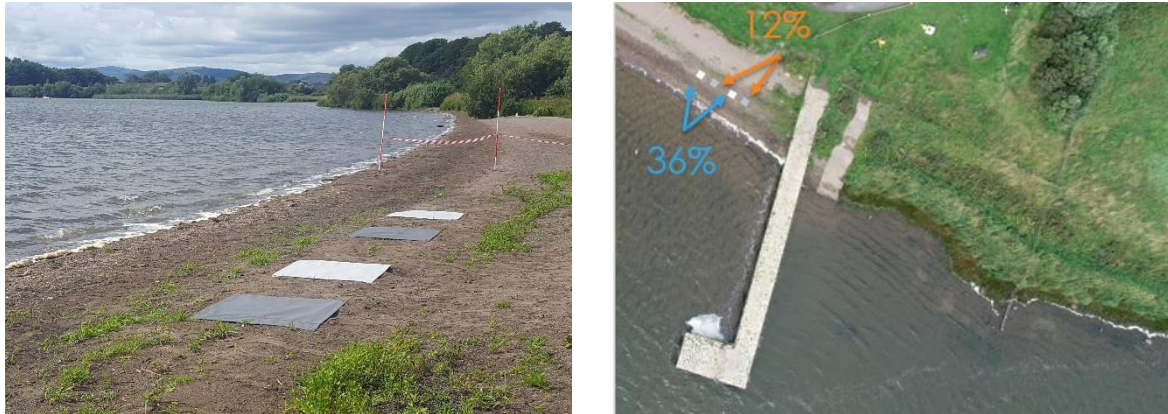


Figure 10 Spectral reference panel placed in the field with known reflectance values: 12% for the dark panels and 36% for the lighter panels.

Data gathering

General considerations

- Position the camera under an angles of 15° from nadir (to avoid sun glint)
- During the flight, the camera should point away from the sun (preferably under an angle of 135° from the sun)
- Check maximum flying altitude, range, ... allowed by the local drone legislation
- Hover at the beginning and end of each flight over the spectral reference targets and take at least 3 pictures.
- Do not put the camera into wet grass: keep camera lenses clean!

DJI flight planning

Introduction

This flight manual explains how to acquire drone data over water surfaces step by step with DJI drones. Deriving quantitative information over water with drones requires careful flight mission planning and a proper camera set-up. This because water bodies are dark objects with low reflectance and can act as a mirror.

The manual list the soft- and hardware requirements, introduces the MONOCLE flight planner and explains the set-up of two different flight scenario's: hovering and mapping. Adequate camera settings are specified.

Requirements

Hardware:

- Drone platform: DJI series
- High Speed SD card min. 64 GB (as raw data are required)

Software:

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- iPad running iOS 10 or higher operating system
- Drone pilot app: GS Pro <https://www.dji.com/be/ground-station-pro>
- DJI GO 4 app
- FTP client (e.g. winscp, <https://winscp.net/eng/download.php>)

Spectral reference panel with albedo of 12%

Monocle Flight Planner

Link: <https://sm-projects-monocle.azurewebsites.net>

App Structure

The **MONOCLE Flight planner** is an online tool which supports drone pilots in defining the correct parameters to set-up a flight plan for data acquisition over water. During data acquisition, the drone pilot has to avoid reflection at the water surface as much as possible. This can be done by looking away from the sun with the camera under a slightly tilted pitch angle of about 15°. To avoid any triangulation calculations in the field, depending on the location of the sun, this tool is a useful guide.

The two parameters which are derived with this tool are the heading of the camera and the Lat and Lon location of the drone with respect to a point of interest (POI).

The app consists of two sections:

1. The first section aids in calculating the angle of the sun on a certain location at a certain time.
2. The second section aids in translating the coordinates of buoys to make sure the pilot can capture the buoys in the centre of the image with a tilted camera (15° from nadir).

Sun Angle

The first section aids in calculating the azimuth angle of the sun on a certain location at a certain time. You provide approximate coordinates for the location of the flight and the table will show you the position of the sun throughout the day.

The azimuth angle of the sun is the angle of the sun relative to true north:

- 0°: sun is in the north
- 90°: sun is in the east
- ±180°: sun is in the south
- -90°: sun is in the west

The angle for flight is the angle the drone should use. This is derived from the azimuth angle of the sun, rotated by 135°. This way the drone and camera always face away from the sun. This angle can be transferred directly into GS Pro as the heading of the drone.

Time: the application always refers to the local time zone.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Coordinate Shifter

The second section aids in translating the coordinates of buoys to make sure the pilot can capture the buoys in the centre of the image with a tilted camera (15° from nadir).

The images below explain how it works. With a tilted camera, the coordinates of the drone are slightly shifted compared to the coordinates of the buoy. In which direction depends on the location of the sun.



Figure 11 Schematic view of the coordinate shifter: with a tilted camera, the coordinates of the drone are slightly shifted compared to the coordinates of the buoy (left). The direction depends on the location of the sun (right).

It is crucial that the drone looks away (preferable under an angle around 135°) from the sun, therefore the camera is not automatically aligned with the direction of the flight lines. **Monocle flight planner** allows you to add multiple locations for conversion.

Comment sections: can be used to indicate which buoy the coordinates represent.

The screenshots below demonstrates a simple example:

For a flight at 14:00 local time, we use the 10° flight angle from the table in the first section. We will be flying at an altitude of 60 m. You then fill in the coordinates of the different buoys and they will appear in the table below. Those coordinates can then be used in GS Pro.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

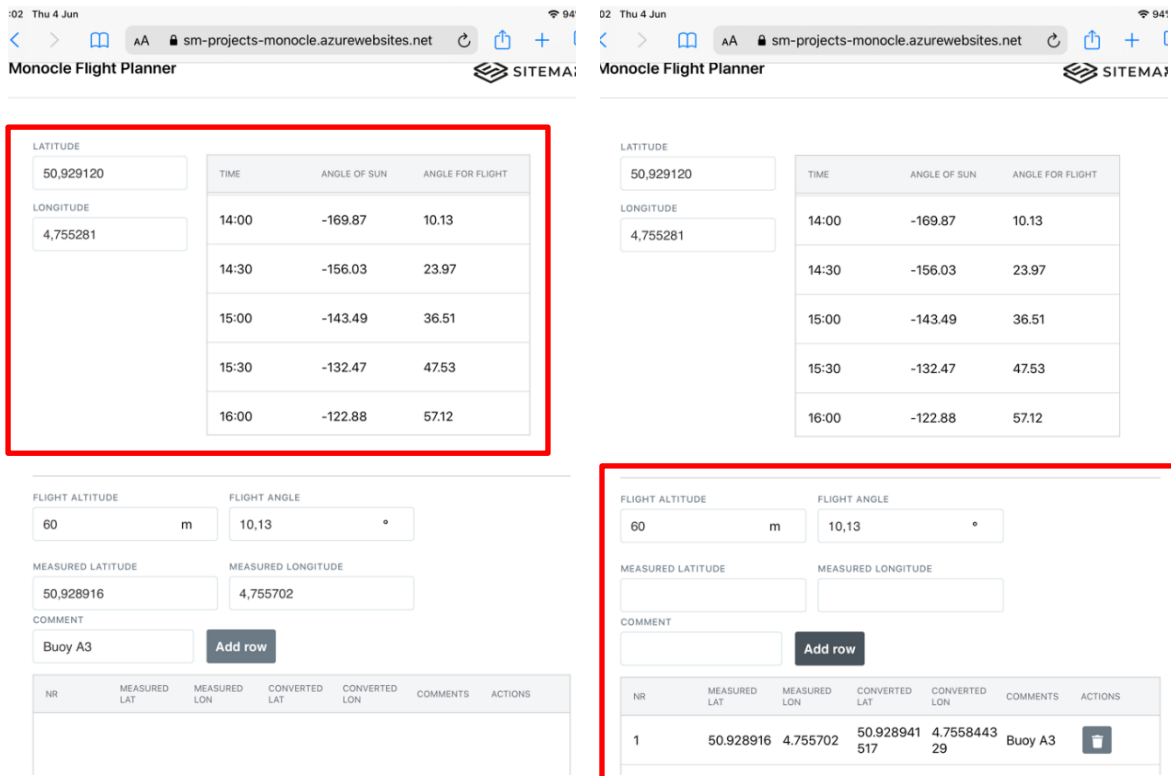


Figure 12 Screenshots taken from the MONOLCE Flight Planner. (Left) By providing latitude and longitude coordinates, you retrieve the angle of the flight throughout the day. (Right) You can fill in the coordinates of the buoys you want to observe and retrieved the drone coordinates, which you can directly insert in the GSpro app.

Flight scenarios


Two flight scenarios for data acquisition over water are foreseen. The first one is a hovering scenario, where data are collected over (a) fixed location(s), e.g. monitoring buoy(s). This hovering can monitor highly dynamic water surface features. Secondly, a mapping scenario is tackled. This is interesting for collecting data over a wider region followed by mosaicking the results.

For both scenarios, the following setting and assumptions are made:

- Flight speed: approx. 4 m/s; return to home speed and towards waypoint_1 up to max 6 m/s
- Height: by default 60 m (confirm with respect to local drone regulations!)
- The take-off and landing of the drone occur at the same location.
- A 12% reflectance, spectrally neutral reference panel is located near the take-off and landing site, with known coordinates. Capture one image with the drone, while lifting the drone at chest height. This image will contain the coordinates of the reference panel.
- At the beginning and end of each flight, once the drone is at flight height, hover over these panels and take at least 5 pictures.
- Always fly with the sun behind the drone (at an angle of 135°). To adequately define the heading, you can make use of the MONOCLE flight planner at <https://sm-projects-monocle.azurewebsites.net>.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Scenario A: Hover & Capture

Step 1: Prepare the GSpro app 

Step 2: Open the Monocle flight app in a different window

Step 3: Select New Mission type – WayPoint Route + Aircraft Record All. To create tackle the Hover & Capture scenario using GS Pro, a waypoint route mission can be used.

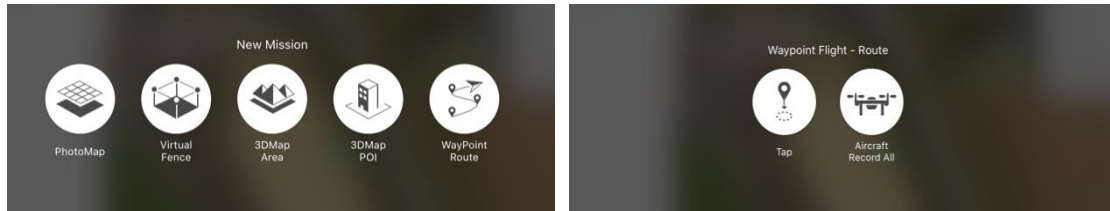


Figure 13 Select New Mission type (left) and choose the Aircraft Record All method (right).

Step 4: Place spectral reflectance panel (12%) nearby take-off location



Figure 14 Spectral reflectance panels placed in the field

Step 5: Perform the Coordinate Reconnaissance flight.

Manually fly over the reflectance panel and over all buoys, centring the points with the camera in nadir to register the coordinates. The drone should hover over each ground control point and take at least 5 pictures. In case you know the coordinates upfront you can skip this and add the coordinates of buoys manually.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

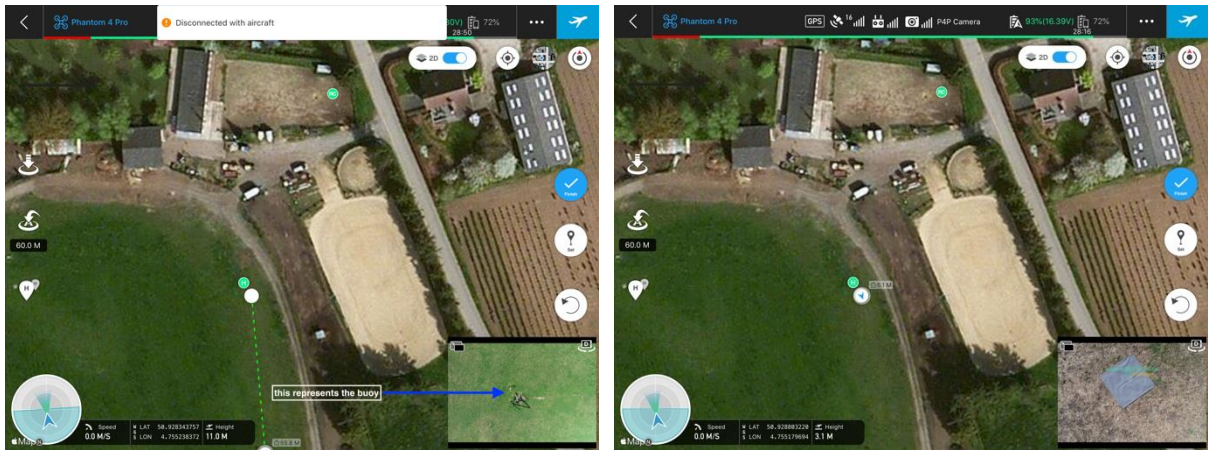


Figure 15 Add the points of the buoys

Once the points are added, the following mission level settings (All Points section in GS Pro) should be used:

- Aircraft Heading: Defined Per Point
- Gimbal Pitch Angle: Defined Per Point
- Cornering: Straight

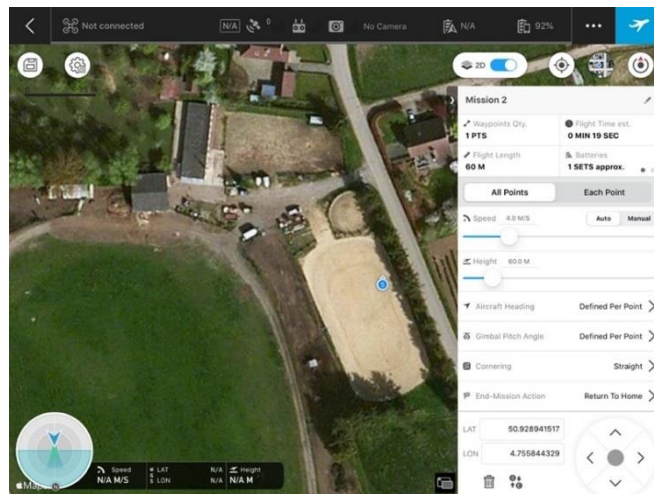


Figure 16 Define mission level settings for all points (All points section in GS Pro)

Then the following mission level settings (**Each Point section in GS Pro**) should be used:

- **Aircraft Heading:** the Angle for Flight as indicated by the Monocle Flight Planner tool
- **Gimbal Pitch Angle:** -75° to make sure it's 15° tilted from nadir
- **Height:** DISABLE

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

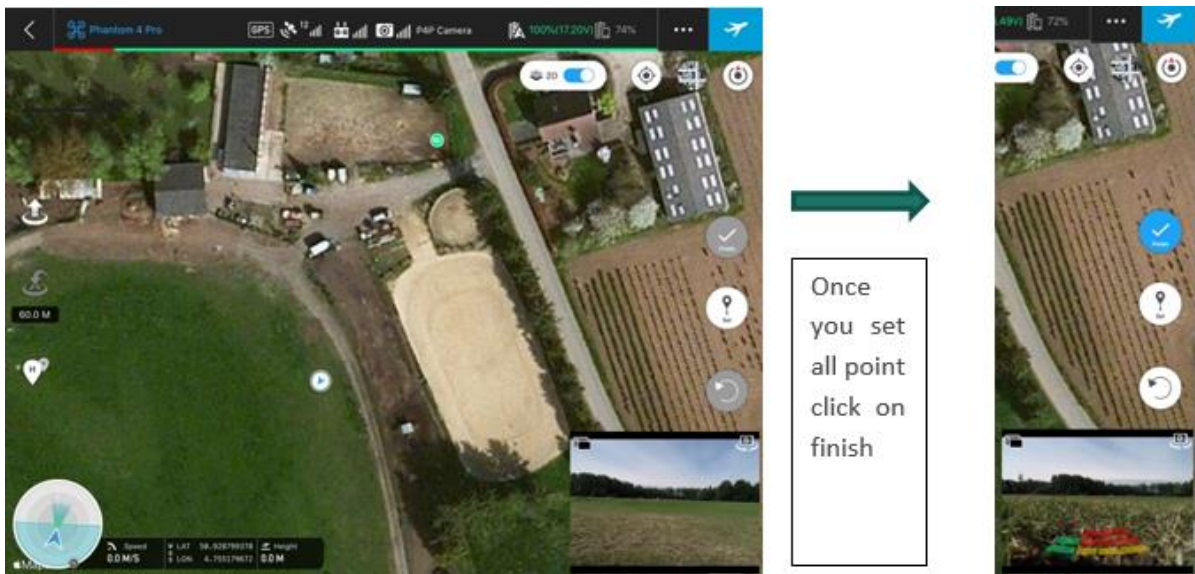
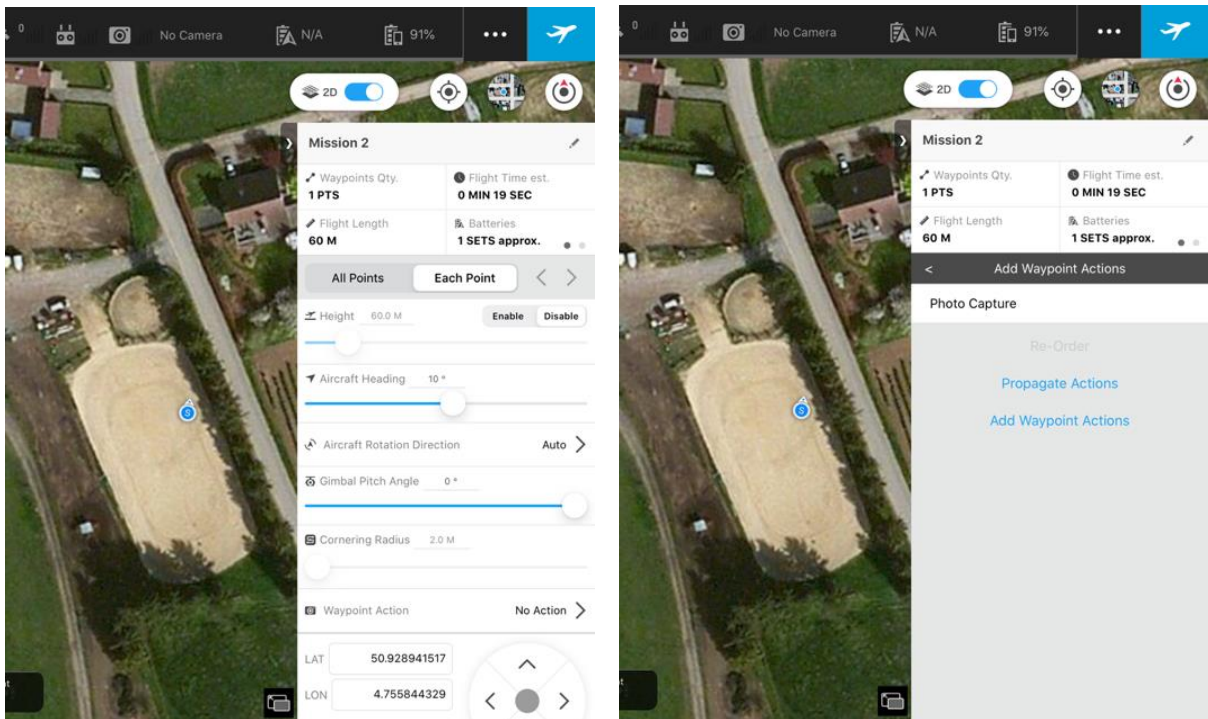
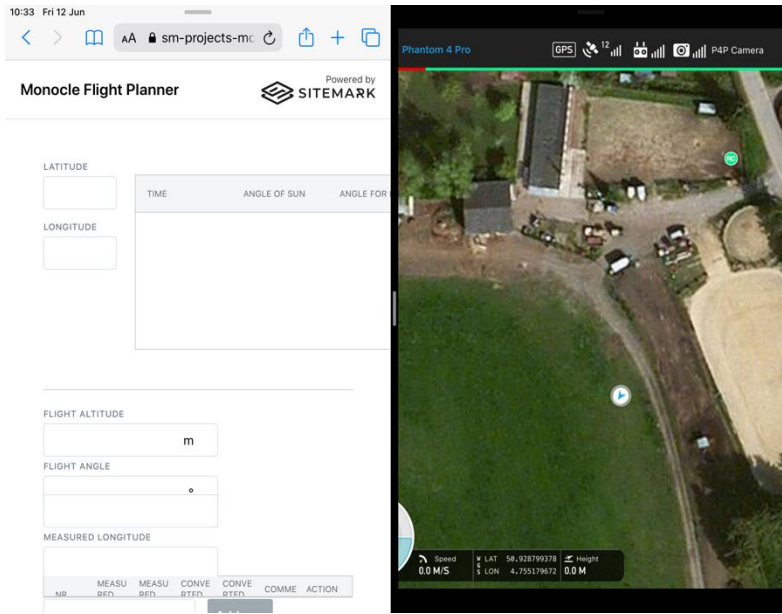


Figure 17 Defining mission level settings for each point and finalize the settings

Step 6: Copy one of the captured coordinates to the first section of the MONOCLE Flight Planner app to calculate the sun and the flight angle.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0



- ❗ You don't have to recalculate this angle for every point, just make sure to take the middle time of the flight.
-
- ❗ Place the Monocle Flight Planner tool side by side with the photos app to easily type over the coordinates

Figure 18 Use the MONOCLE flight planner tool to derive the correct drone coordinates if you want to hover over a predefined location (e.g. buoy)

Select the time of the flight

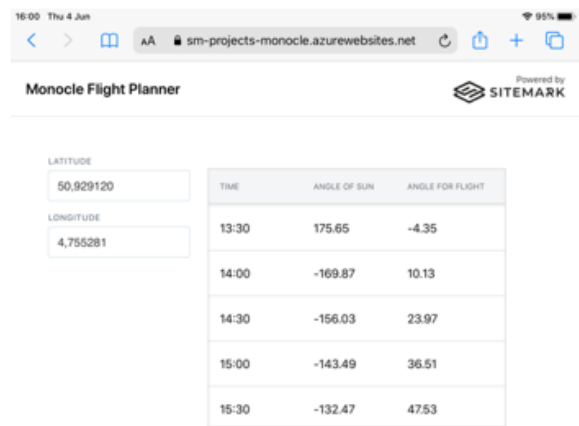


Figure 19 After copying the coordinates, select the time of the flight to retrieve the correct angle towards the sun.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Step 7: Take over the coordinates of the reflectance panel and the buoys into the coordinate convertor and copy the results to GS Pro where you can update the coordinates (under each point).

The figure illustrates the process of defining coordinates for a reflectance panel and buoys. It consists of three main parts:

- Web Interface (Left):** Shows the 'Monocle Flight Planner' with input fields for Latitude (50.929120) and Longitude (4.755281). A table below shows the 'ANGLE OF SUN' and 'ANGLE FOR FLIGHT' for various times from 14:00 to 16:00. Below this, there are fields for 'FLIGHT ALTITUDE' (60 m) and 'FLIGHT ANGLE' (10.13 degrees). There are also fields for 'MEASURED LATITUDE' (50.928916) and 'MEASURED LONGITUDE' (4.755702), and a 'COMMENT' field containing 'Buoy A3'.
- Web Interface (Middle):** Shows the same interface with the 'Add row' button highlighted. Below it, a table shows the converted coordinates for 'Buoy A3':

NR	MEASURED LAT	MEASURED LONG	CONVERTED LAT	CONVERTED LONG	COMMENTS	ACTIONS
1	50.928916	4.755702	50.928941517	4.755844329	Buoy A3	[Icon]
- Mobile App (Right):** Shows the 'GS Pro' app interface with a map and a keyboard overlay. A green arrow points from the converted coordinates in the middle screenshot to the input field in the mobile app, indicating the transfer of data.

Figure 20 Define the coordinates of the reflectance panel and the buoys into converter and copy the results to GS Pro.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Click on Each Point

Copy & Paste the coordinates

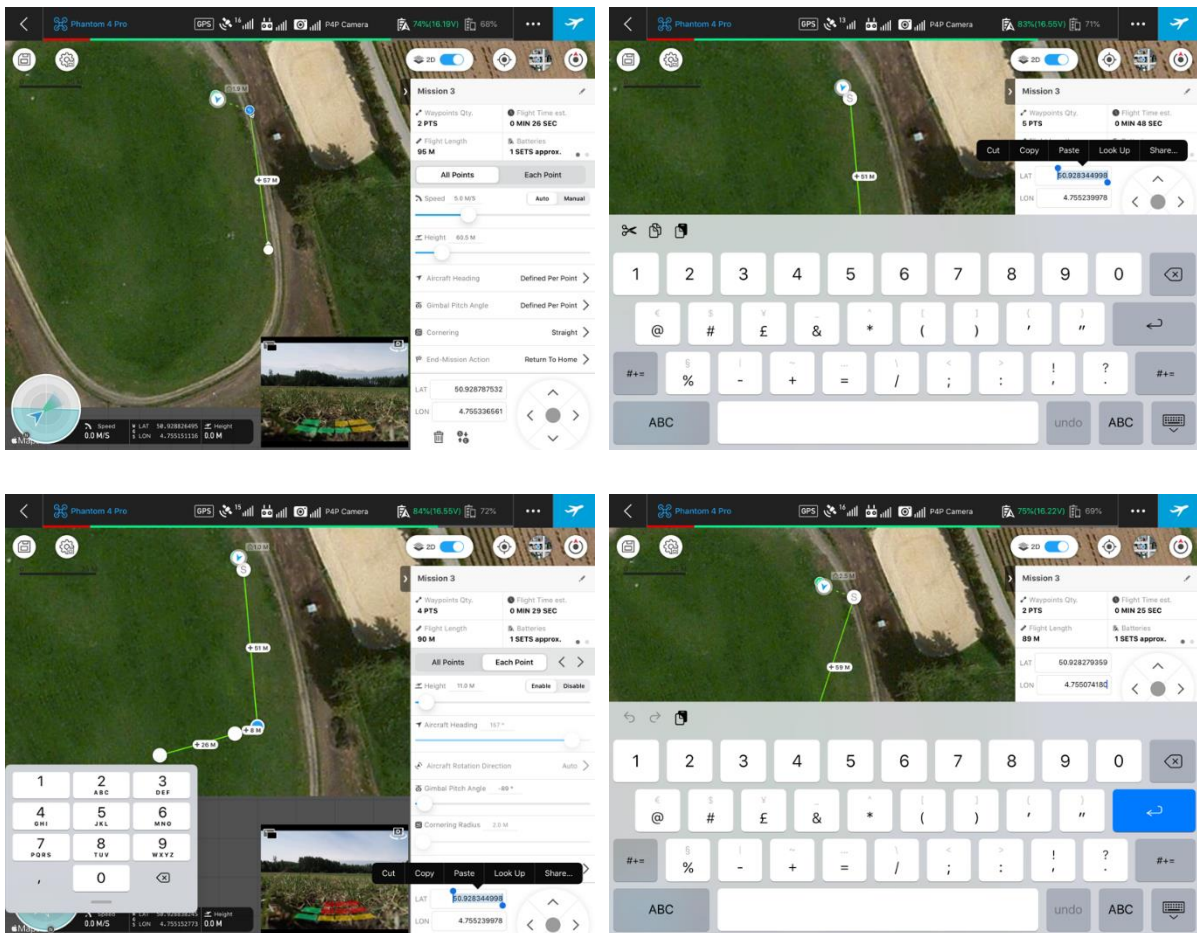


Figure 21 You can copy-paste the retrieved coordinates in the Lat Lon field, selected in the figures above.

Once all the converted coordinates are entered you can start flying. To do so, set up the camera as guided.

Step 9: Flying parameters in GSPRO. Select the parameters as below:

All points

- Speed: 4.0 m/s
- Height: 60.0 m
- Aircraft Heading: Defined per point
- Gimbal Pitch Angle: Defined per point
- Cornering: Straight

Each point

- Aircraft Heading: 10 degrees
- Gimbal Pitch Angle: 0 degrees

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

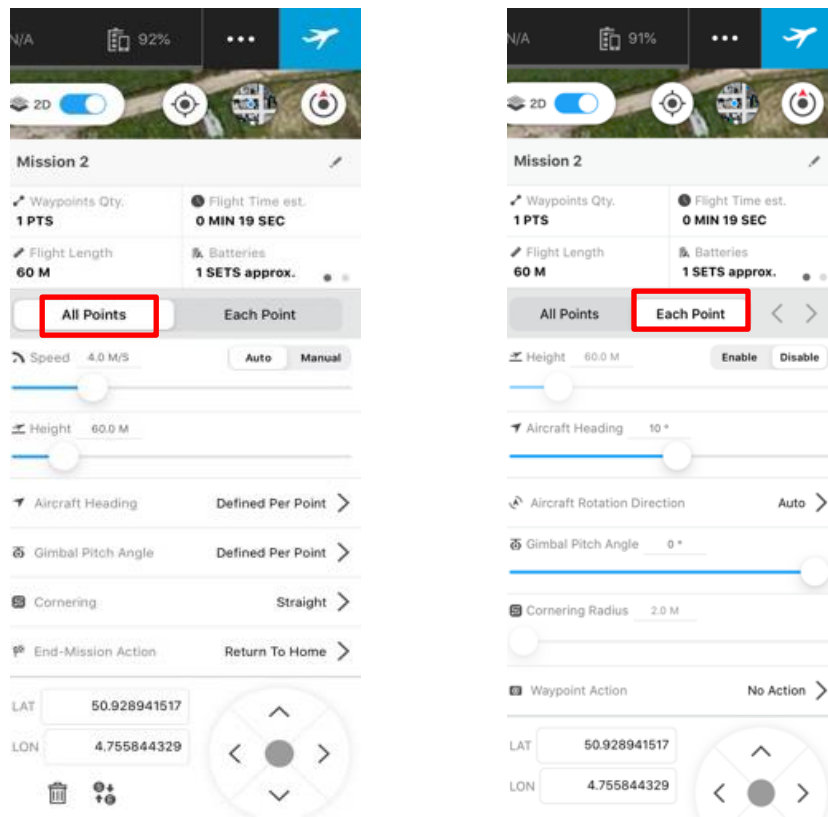


Figure 22 Set the flying parameters for All Points (left) and Each Point (right) correct.

Add waypoint actions (for 6 photos we need to propagate the action 5 times to ensure the drone will take 5 consecutive photos).



Figure 23 Capture a couple of images when hovering over a buoy.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Add Waypoint Actions

Create a Photo Capture 5 x times and under always propagate an action: Hover 10sec. Choose to propagate actions to – **ALL OTHERS**

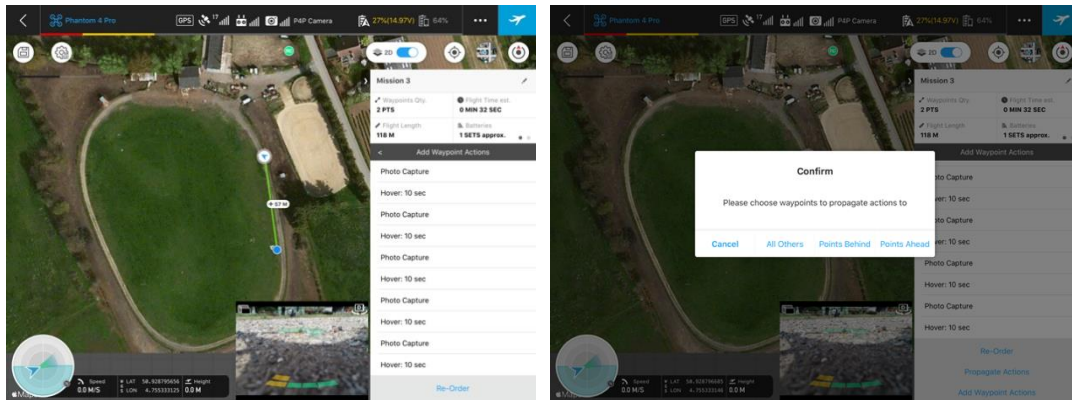


Figure 24 Add waypoint actions.

Scenario B: Mapping Flight

- Bounding box, with GCP's Included is given → Drone monitors the area
- Overlap requirements: minimum of 80% for RGB camera
- When battery is getting empty → drone lands in time.
- RGB camera at 15° to nadir, also during flight (in case of only RGB)

Step 1: Prepare the GSpro app

Step 2: Open the Monocle flight app in a different window

Step 3: Select New Mission type – 3DMap Area + Tap or Aircraft

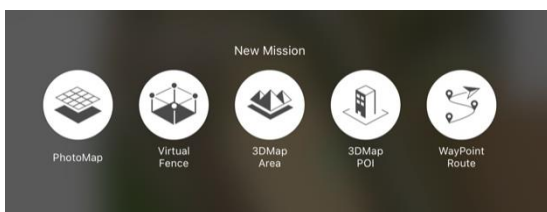


Figure 25 Selection New Mission type

Step 4: import kml (if no .kml file available please create the mission manually)

Go to the mission section – Material – Start Import – upload the kml via the default link.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

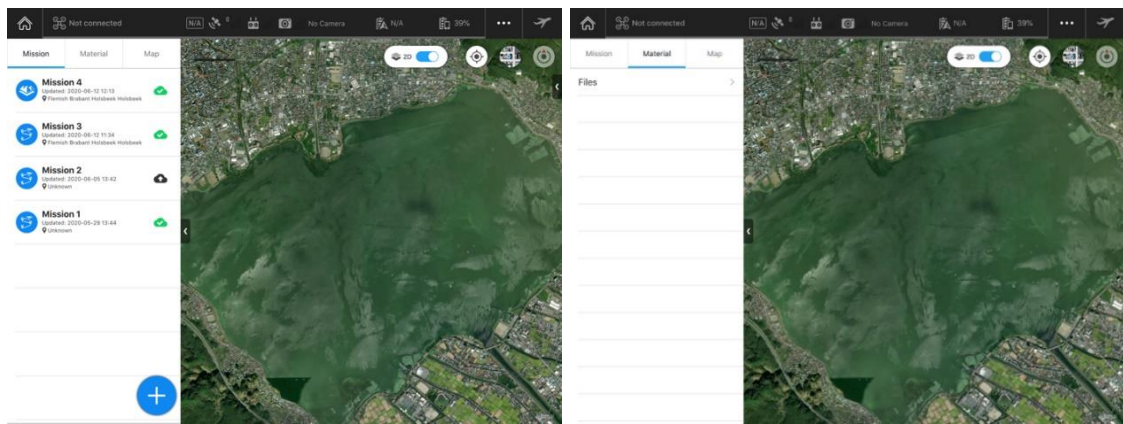


Figure 26 Go to mission section (left) and choose the Material tab (right).

Click on **Start Import**

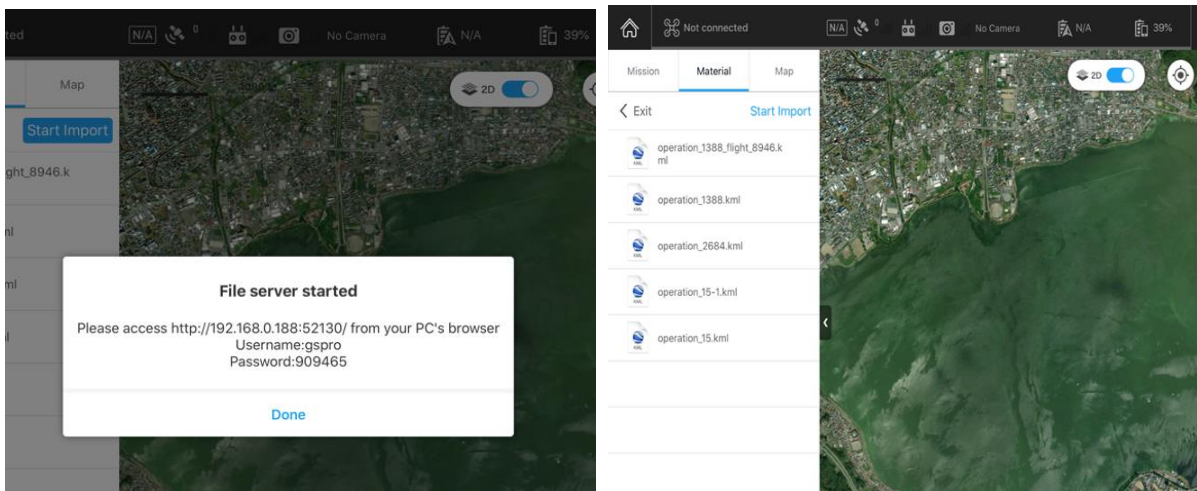


Figure 27 Once you've started to import the files, you will receive a message "File Server started" (left), and upon completion the kml files will be visible in the Material tab (right).

Slide to the left to **Create a mission**. You will receive the three options. Select the 3D map area

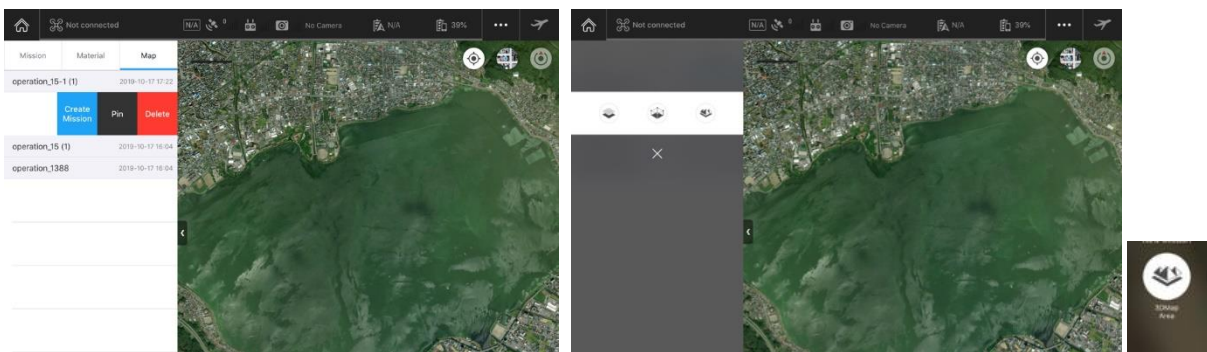


Figure 28 By sliding to the left you can create a new mission (left). Select the 3D map area (icon on the right).

Or if you do not have a kml you can select **Map** – and choose the place

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

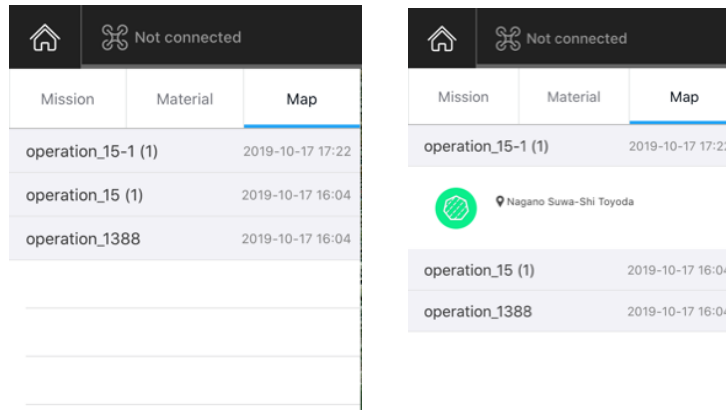


Figure 29 In case no kml is available, go to Map tab and choose the location.

Step 5: Set up the Basic and Advanced

Basic

- **Camera Model:** choose your RGB camera from the list
- **Shooting Angle:** Perpendicular to Course (used to be Perpendicular to MainPath)
- **Capture Mode:** Capture at Equal Time Interval
- **Flight course Mode:** Inside mode
- **Height:** 50.0 M

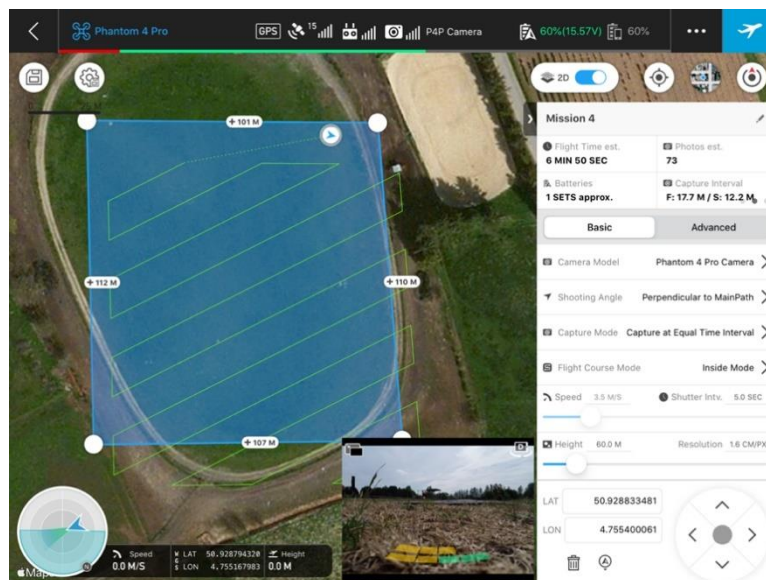


Figure 30 Overview of basic settings

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

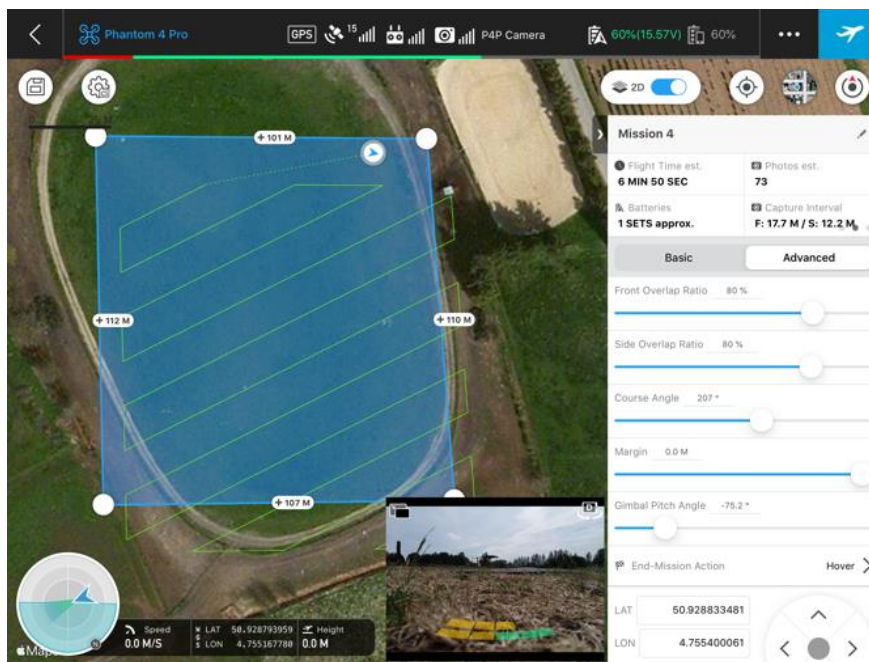
Flight Angle

For the calculation of the flight angle in the mapping scenario you should do the following: if the flight angle coming from our tool is between -180 and 90, you should add 270. If it's between 90 and 180, you should subtract 90.

Two examples:

Example A: In our example the flight angle was -63, which is between -180 and 90. Adding 270 gives 207.

Example B: If the angle for example was 104, it's between 90 and 180. Subtracting 90 gives 14.



Advanced

Overlap: 80% 80%

Figure 31 Overview of advanced settings

Camera settings

Flying RGB camera – summary

a. Camera settings:

- “ F-stop fixed” (4.5)
- White balance: fixed: sunny or cloudy
- Focus on infinity
- Light Measuring mode (partial metering or centre-weighted average metering)
- Shutter mode = s (shutter speed priority)
- Shutter iso = auto
- Shutter time = 1/2000 (sun) or 1/1000 (clouded)
- Always zoomed out
- Type of image: **RAW***

b. Drone settings:


Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Side overlap: 80%
- Front overlap: 80%

- ❗ If the weather conditions are stable, it's fine to just capture the reflection panel at the beginning and ending of each flight.
 - Otherwise, you should capture it between every buoy

GSPro settings (explanation)

- Camera Settings

 : Tap to set the ISO, Shutter Speed, F-number and Exposure Value of the camera, Capture Mode, Image Size, Image Format and White Balance, AF Assistant, MF Assistant and Grid.

- Map

Tap the map to return to the Map View. Tap the icon in the left top corner to minimize the map.



Set up the parameters as below:



Shutter mode = S (shutter speed priority)

F-stop fixed = (4.5)

Shutter time = 1/2000 (sun) or **1/1000** (clouded)

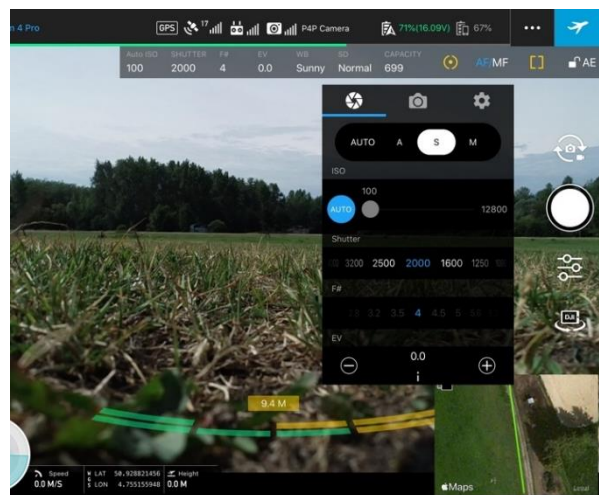
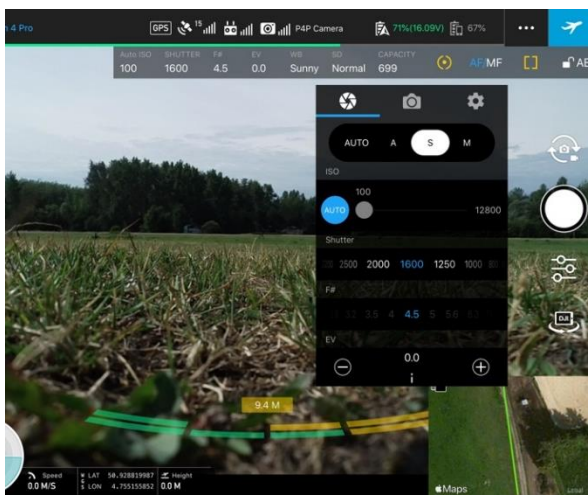


Figure 32 Define camera settings. Shutter time is 1/2000 for sunny conditions (left) and 1/1000 on cloudy sky conditions.

Select Image size: 3:2 / Image Format: RAW

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

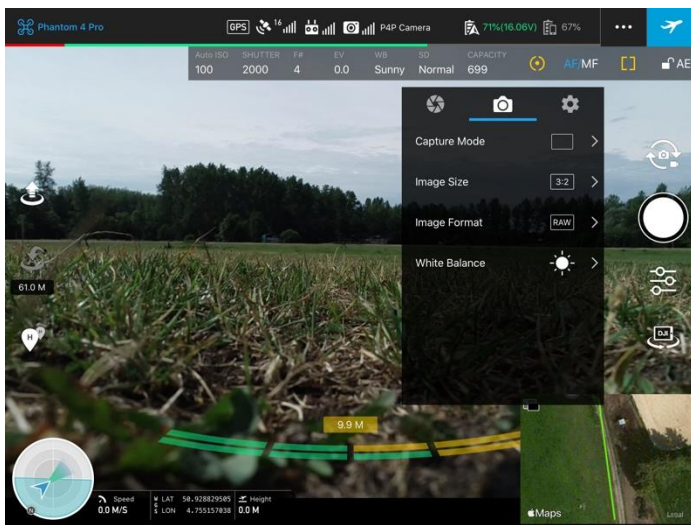
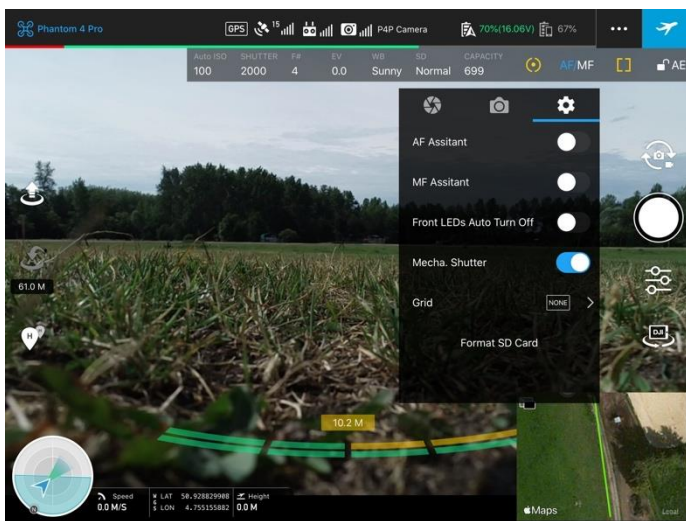


Figure 33 Set the image size and image format correctly. The image format should be RAW.

Mechanical Shutter – ON

Grid → you can choose a grid in order to centre the buoys for example while looking at the camera - it will give you a squares for better detail



Grid Diagonal

Grid Line

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

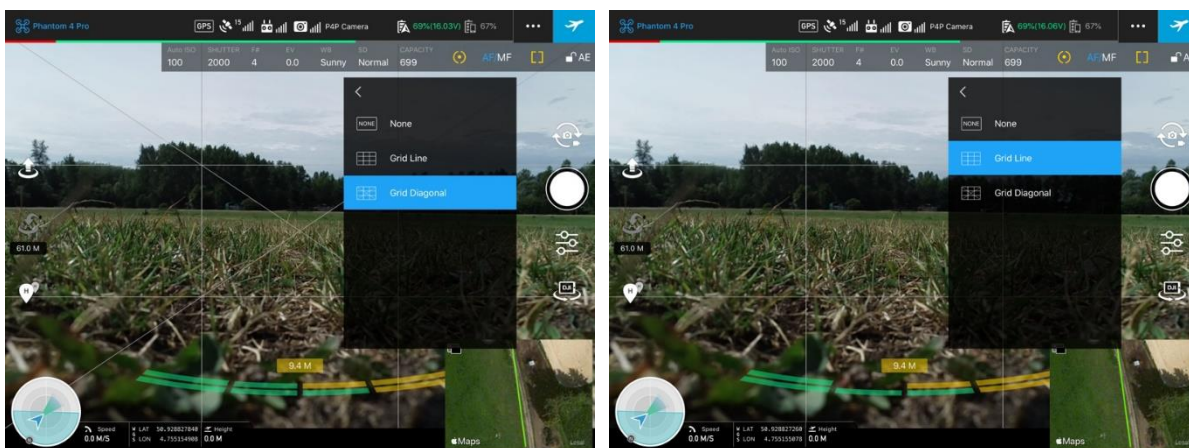


Figure 34 Define the preferred gridding

Capturing RAW Images

Unfortunately, GS Pro doesn't allow capturing RAW images during a mapping flight by default. In order to correctly take RAW images, you should do the following:

- Optional Step: Add a custom camera to GS Pro that mimics the camera you're trying to use (most likely Phantom 4 Pro), but that has a larger minimum capture interval. Example settings for the Phantom 4 Pro:

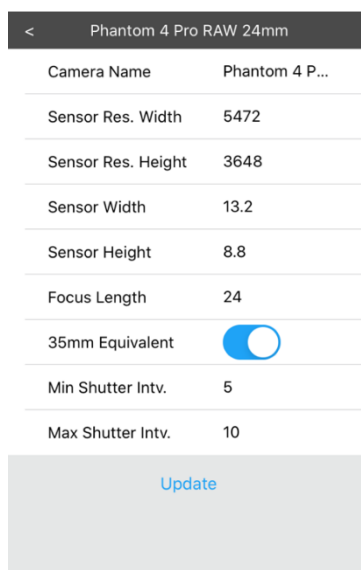


Figure 35 Example settings for the Phantom 4 Pro.

- Set up the flight as usual. You'll notice that the flight speed of the mission is now much lower, because the capture interval is set to 5 seconds automatically.
- Take off manually and fly away from the starting point of the mission. This will give the pilot more time to switch between apps and change settings.
- In the GSPro app start the mission.
- Launch the flight and immediately switch to DJI Go 4 to alter the camera settings.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Since you're switching apps, you have to disconnect the lightning cable from the iPad and plug it back in. This will now connect DJI Go 4 instead of GS Pro.
- Open the camera settings and change the file format to RAW.
- Confirm that the DJI Go 4 app follows the waypoints defined by GSPRO app. Supervise the flight within the DJI Go 4 app till the mission ends and the drone return to home.

Your mission should have been completed capturing RAW photos.

Data check

During flight

- Check the camera is oriented away from the sun
- Check the RGB camera keeps pointing 15 degree offset
- Check whether the reference panels are visible in the live stream
- Check the drone battery status. Take into account that the time from ending the flight plan till landing can take several minutes.

After flight

- Check that SD cards are not completely full
- Check if captured data are in RAW format
- Quick check on GPS
- Quick check on camera settings
- Check image saturation
- Look for reference panels in the images

Data upload - MAPEO field software

The MAPEO field software tool has two purposes:

- Check if drone data acquired meets the quality requirement for further uploading and processing in the MAPEO backend.
- Perform the actual upload to the MAPEO backend.

The verification step is conducted in the field, just after the drone mission has been flown, to analyse data quality and coverage. Data upload can be carried out back in the office once a high speed internet connection is available.

System requirements

- Java capable computer with minimally 1 GB – preferably 2GB of RAM
- Java version 8 or higher – Since April 2019, Oracle Java works via a licensing system for commercial use. So, the download at <https://www.java.com/nl/download/> is only intended for personal or demonstration use
- Internet access for Java – on first run: Some firewall/internal policies block access or present a pop up when launching Java for the first time, you must allow Internet access.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

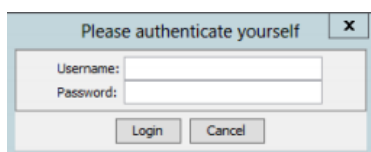
Software installation

You should have received a link to a jar file (uav-pc-fieldsoftware-rgb-0.9.28.jar). Download it somewhere locally on your hard drive, no install is needed. Then double click on it to run the application.

Alternatively, you can open the jar by running it via the “java -jar uav-pc-fieldsoftware-rgb-0.9.28.jar” command.

Authentication – logging in

When you open the Field software for the first time, a log-window will pop-up.



At this point, you need internet access. After successful authentication, you are no longer required to login for a period of 60 days. The username is cached on the Windows user account on the pc.

So, before going in the field without internet access, you should have run the jar at least once and logged in for the active Windows user!

Creating new mission

On the opening page, you will see a BING map indicating all the locations which have been flown. You can either edit the previous loaded missions or add a new mission by clicking “new” button, which you usually do when you start a new verification procedure or upload.

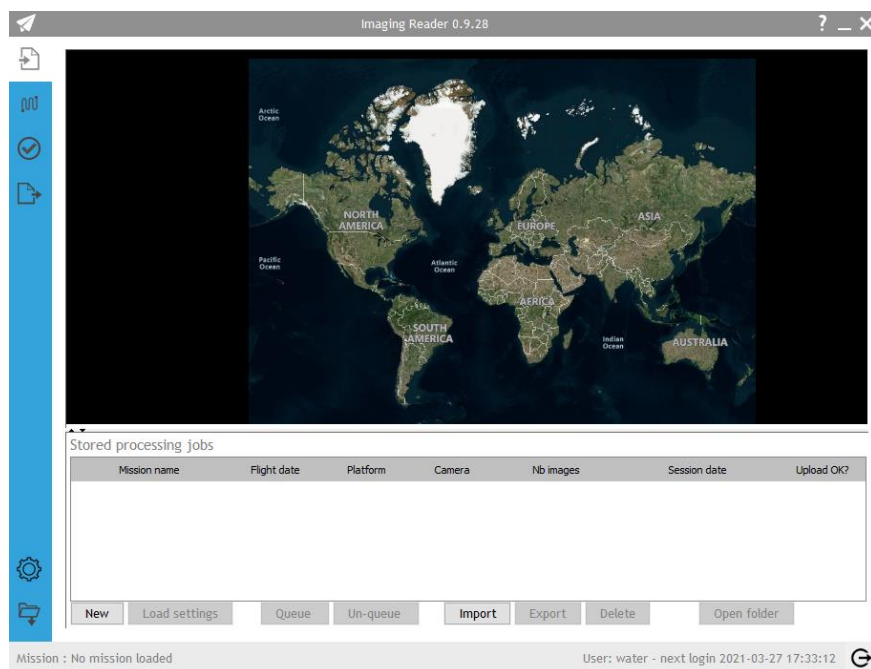


Figure 36 MAPEO field software opening page. To create a new mission, click the “New” button.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Step 1: Select mission profile

In the first step of a mission creation, you select the appropriate mission profile. A mission profile defines the parameters to be used for a specific type of missions, closely linked to the sensor type. You can choose a predefined profile (managed in the cloud by VITO) or one that you created locally.

The selected profile will be used to prepopulate the mission specific profile, which is shown in this screen. So, you can modify the mission specific parameters. Only if you want to reuse the settings later, you need to click on “Store profile”.

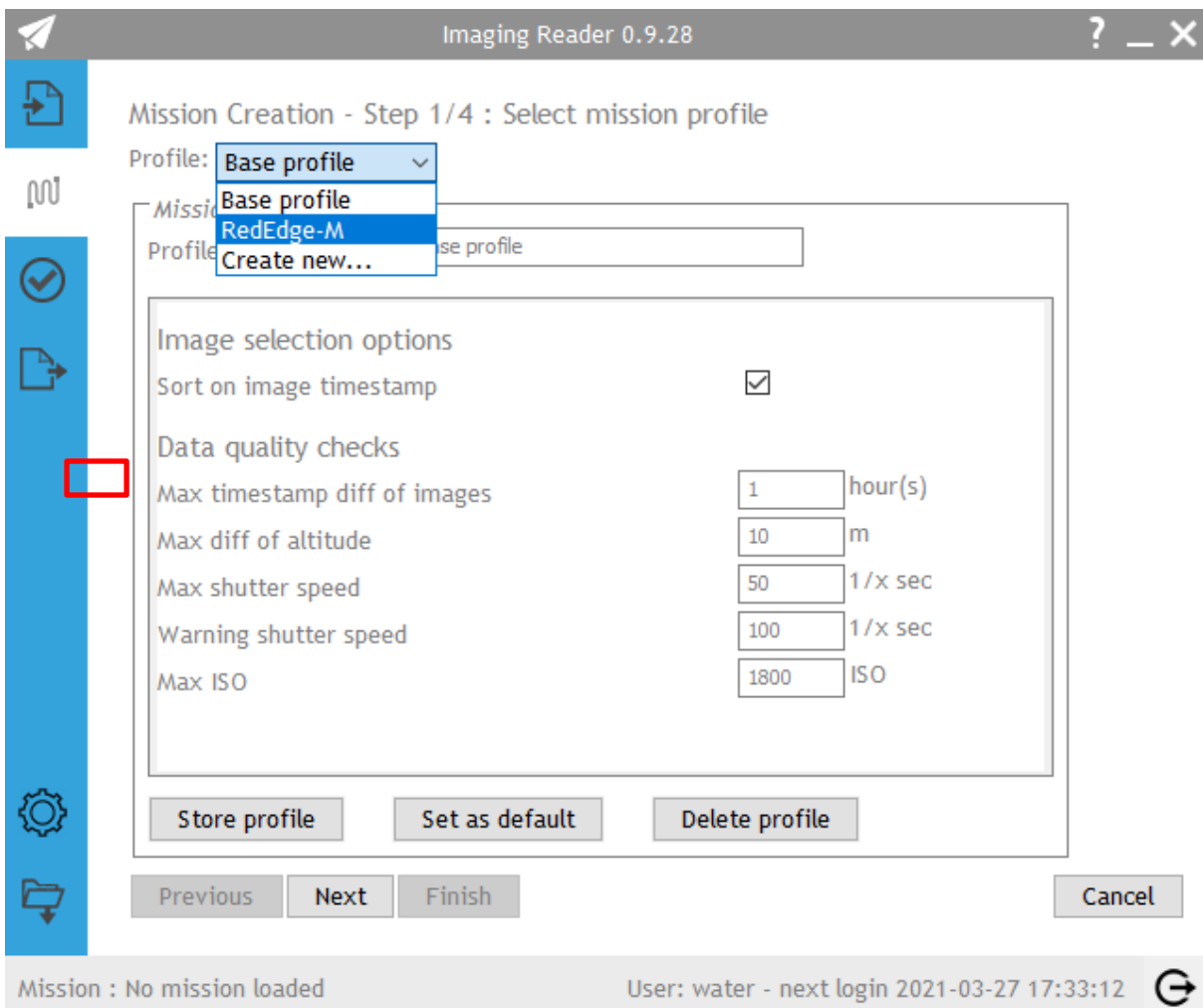


Figure 37 Create a mission profile

The following parameters can be set:

Profile name: you only need to change this if you want to store this mission profile to be reused in later mission

Image selection options:

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Sort on image timestamp: If you check this box, the flight lines of a mission will be computed and sequenced, based on the image timestamp. If not checked, the flight lines are sequenced based on the alphabetically sorted image names.

Data quality thresholds:

Max timestamp diff of images: Maximum difference in timestamp of individual images, ensuring no old data ends up in a new mission.

Minimal diff of altitude: Minimal altitude difference in meters for one mission, ensuring stable height of the flight and consistent resolution of the drone based products.

Max. shutter speed: Maximal shutter speed in 1/x seconds

Warning shutter speed Maximal shutter speed – warning value

Max ISO: Maximal iso value

Step 2: Image selection

2.1 Loading drone images

To select images for upload, press on the “Select Image folder” and browse to the folder where the drone images are stored. Note that for large missions, the dataset loading may take a few minutes (especially on slow internet connection).

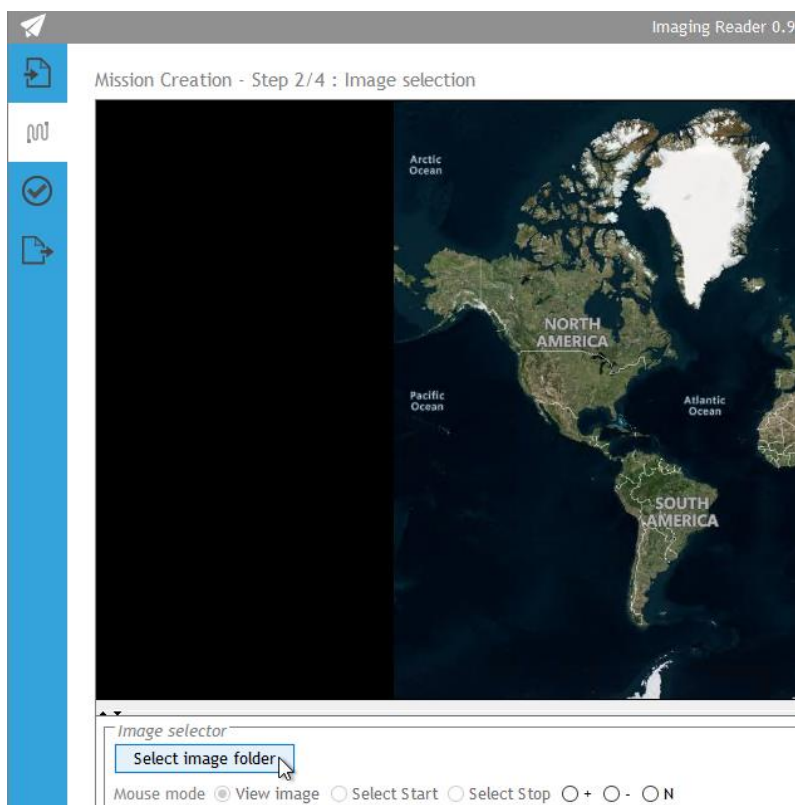


Figure 38 Select image folder to browse to the folder where your images are stored.

When it finishes, the image names will be listed along with their positions

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

At this point, you get a visualisation of all image locations by dots, and a table list with all images. The header of the table gives you the number of images to be processed. Unselected images are represented by an orange dot, selected images with a black dot.

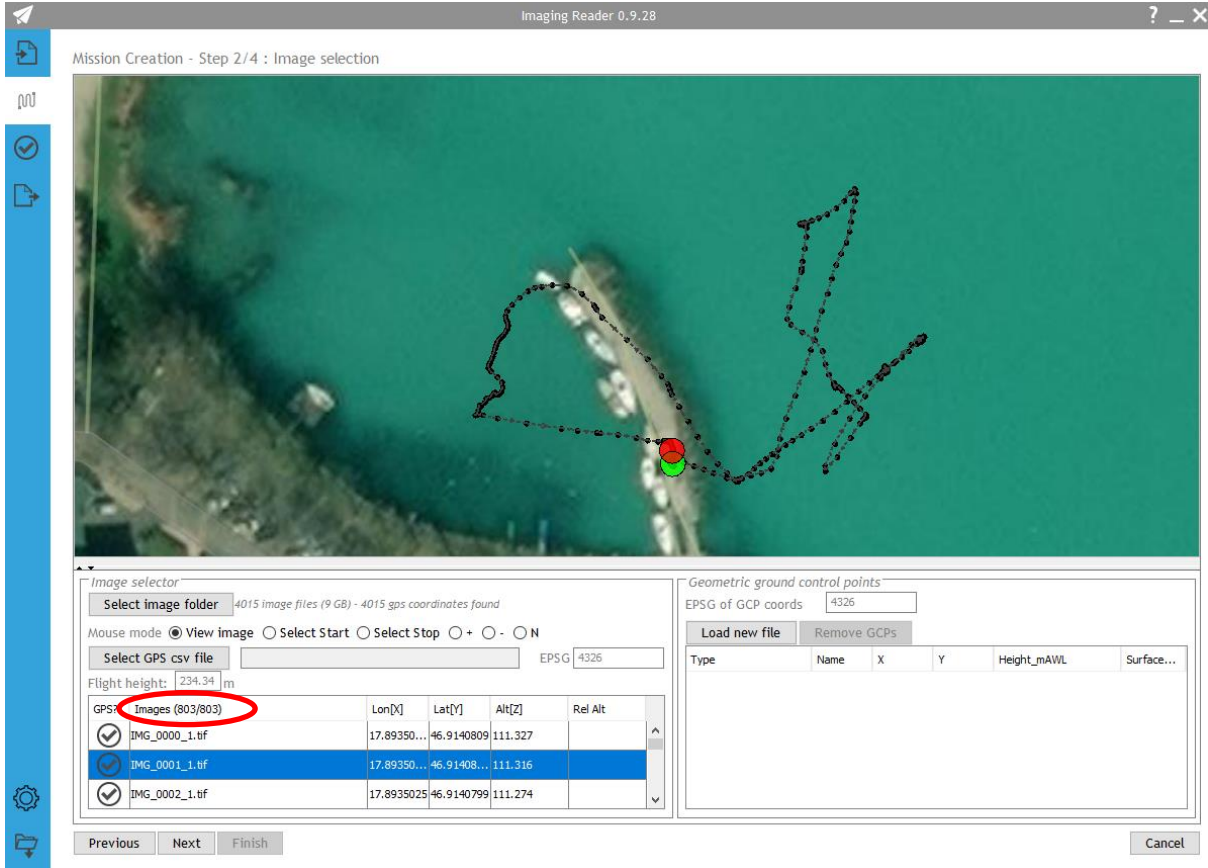


Figure 39 Once images are loaded, they are shown in the viewer. Orange dots are unselected images, while black dots are selected. You can also see the total number of images selected in the header of the images column (marked with red circle).

Hint: you can also use the table to export gps data. Click an entry, select "CTRL-A" "CTRL-C" and you can paste the coordinates in for example Excel. Note that this table selection also selects the images for processing so click anywhere to revert that.

2.2 Visualizing individual drone images

IMPORTANT - Zooming:

Use the mouse **SCROLL** to zoom in/out in steps

Use **SHIFT** mouse drag to zoom in to the selected square

Click anywhere on the screen to return to default zoom level for the mission

Individual images can be visualized in view image mode by clicking the corresponding image position in the main window:

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

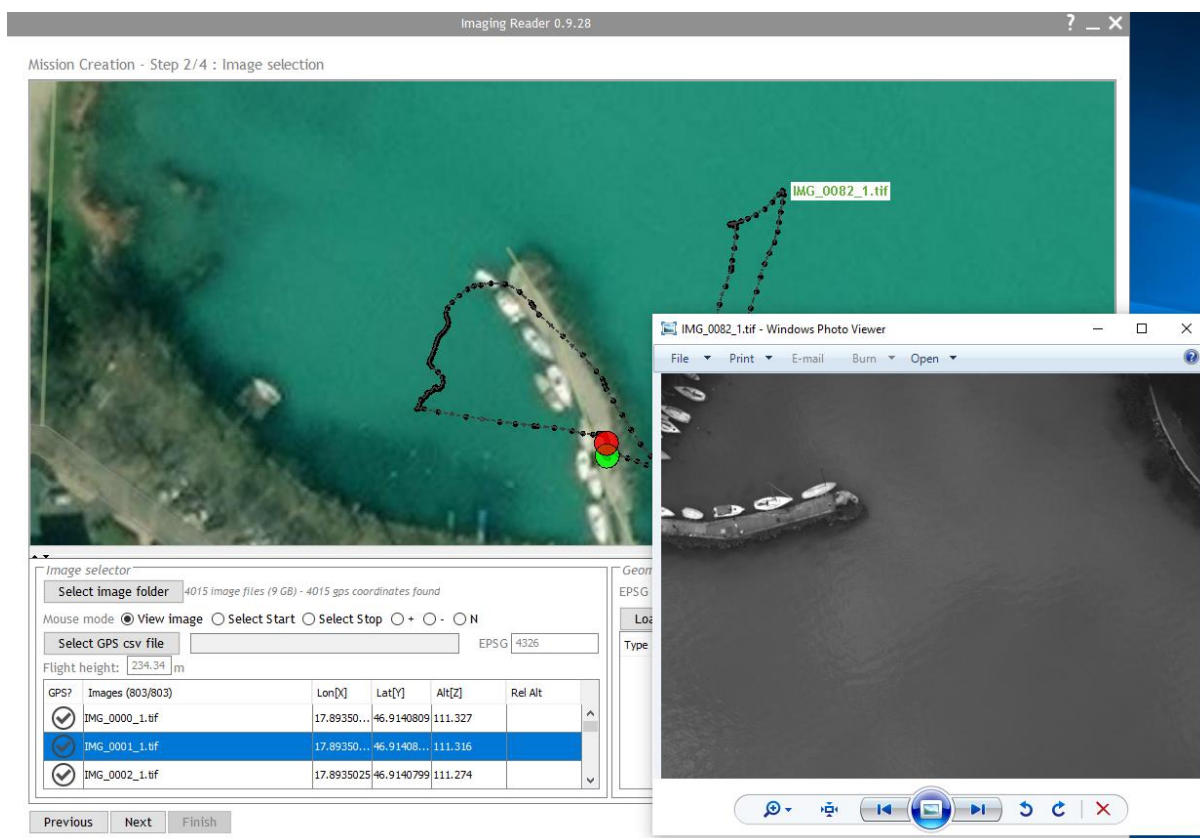


Figure 40 Visualisation of one drone image by clicking on the corresponding dot.

2.3 Defining start and stop position of the drone flight

You must specify the **start and end positions** of your mission by selecting “Select start” and “select stop” buttons and clicking on a point representing the camera position. Note that all images before the start position and after the end position will not be considered for image upload nor processing (they will have an orange colour, selected images are coloured in black).

The user can also **select/deselect images manually** using the + and – mouse mode, forcing selection/deselection by dragging a box around the relevant points. The N-button will remove any selection hints by the user.

2.4 Defining geometric ground control points

You can include information on the ground control points, by clicking the ‘Load new file’ in the ‘Geometric ground control points’ box to upload a CSV file (delimiter = TAB) containing information about the reflectance panels.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

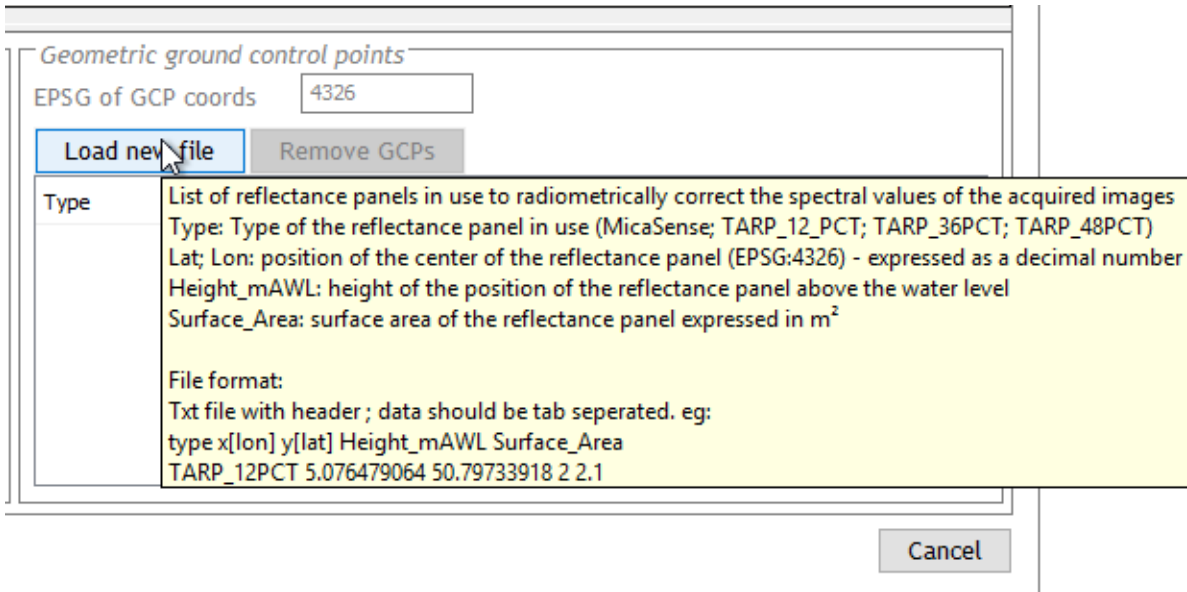


Figure 41 You can load a list a reflectance panels in the mission. The file has to follow a predefined file format structure.

NOTE that the coordinate system used for the GCPs is in EPSG:4326

In the map overview the GCPs are visualized as red dots. The template for the tab separated csv format is given below:

type	x[lon]	y[lat]	Height_mAWL	Surface_Area
TARP_12PCT	17.89348	46.91414	2	2.1
TARP_36PCT	17.89346	46.91416	3	3.1

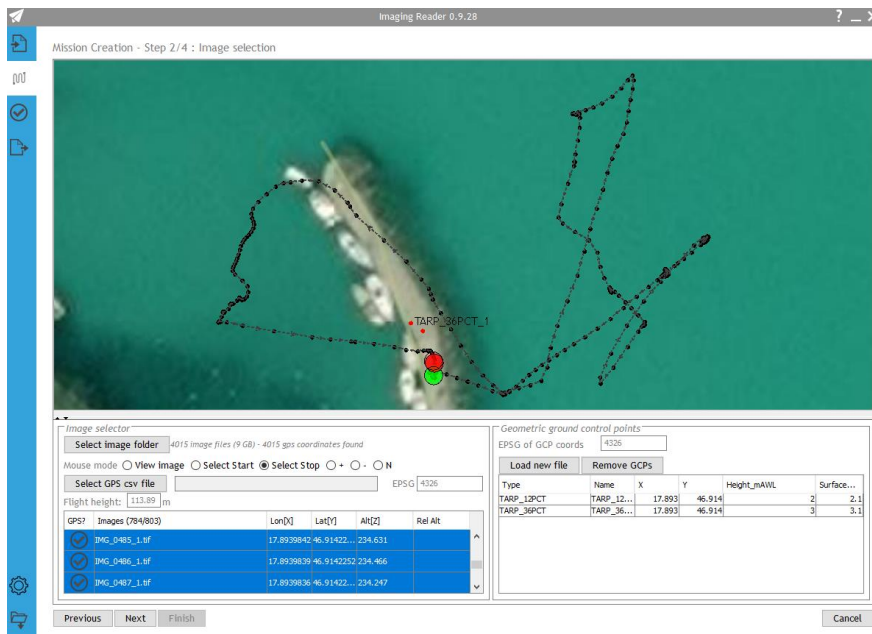


Figure 42 Geometric ground control points are added as red dots to the viewer.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Once all images are loaded, selected and ground control points are added, you can press the “Next” button at the bottom of the window to go to the next step.

Step 3: Flight description

After clicking “next”, you go to the flight description page containing some additional mission metadata. Most parameters (indicated with a (*)) are set automatically from the image metadata, but a manual correction or change of these parameters is still possible.

Imaging Reader 0.9.28

Mission Creation - Step 3/4 : Flight description

Flight

Date (yyyy/mm/dd) (*) 2019/07/03

Time (hh:mm) (*) 12:00:08

Location

Flight nb 1

Altitude Water level

Altitude take-off location

Flight description

Operator

Name

Email robrecht.moelans@vito.be

Camera

INS type MICA

Camera type MSREM

Camera offset x (cm) 0

Camera offset y (cm) 0

Camera offset z (cm) 0

Camera angle x (°) 0

Camera angle y (°) 0

Camera angle z (°) 0

Irradiance sensor MSREM

Irradiance sensor type

Irr. sensor vector coord x 0

Irr. sensor vector coord y 0

Irr. sensor vector coord z 0

Model (*) RedEdge-M

Serial Lens (*) RM01-1817119-SC

Platform

Brand (*) MicaSense

Model (*) RedEdge-M

Previous Next Finish Cancel

Figure 43 Flight description parameters. The different parameters are described in the text below.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

The following parameters can be set:

Flight

Date (yyyy/mm/dd) (*) : Date of data acquisition

Time (hh:mm) (*): Time of data acquisition

Location: You can give a name to the location where you've collected your images.

Flight nb: Flight number

Altitude Water level: Altitude of the water level with reference to GPS altitude reference

Altitude take-off location: Altitude of the take-off location with reference to the GPS altitude reference

Flight description: You can include a description of the flight

Operator

Name: Name of the operator

Email: Email address of the operator

Camera

INS type: Choose between the different INS (Inertial Navigation System) options. Currently two options are supported:

- PH4P: Phantom 4 pro INS system
- MICA: Micasense INS system.

Camera type: Choose between the different camera options. Currently two camera sensors are supported:

- PH4RGB: Phantom 4 RGB camera
- MSREM: Micasense RedEdg-M camera

Camera offset x (cm): Offset of the camera towards the front

Camera offset y (cm): Offset of the camera to the right, view from the top.

Camera offset z (cm): Offset of the camera down (positive sign= camera shifted downwards).

Camera angle x (°): Roll angle of the camera, defined counter-clockwise (+) as seen from the front of the drone.

Camera angle y (°): Pitch angle of the camera, a positive angle (+) means that the camera is tilted forwards and looks in front of the drone position.

Camera angle z (°) : Yaw angle of the camera, a positive angle (+) means a clockwise rotation of the camera with regard to the orientation of the drone as seen from the top.

Irradiance sensor: You can choose in the drop-down menu between:

- PH4RGB: Phantom 4 RGB camera
- MSREM: Micasense RedEdg-M irradiance set-up

Irradiance type: There are two irradiance types supported: Micasense DLS-1 and DLS-2 (Downwelling Light Sensor)

Irr. sensor vector coord x: Offset of the irradiance towards the front

Irr. sensor vector coord y: Offset of the camera to the right, view from the top

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Irr. sensor vector coord z: If the irradiance sensor is installed vertically upwards on the drone platform, this z-value should have a value of -1.

Model (*): The model of the camera. This information will be automatically updated when an image folder has been selected.

Serial Lens (*): The serial number of the camera. This information will be automatically updated when an image folder has been selected.

Platform

Brand (*):This information will be automatically updated when an image folder has been selected.

Model (*): This information will be automatically updated when an image folder has been selected.

Session

Session: If a new session is created, the date and time at that moment are given defined for that session.

Step 4: Product and processing options

This step let the user set up and select what will be executed from the processing workflow. There are three options foreseen:

- Predefined (default option): this option runs through the full data processing workflow.
- Remote config file: There is an option to work with remotely defined configuration files. configBase.py and configNoEndProduct.py.
- Local config file: the user can upload a local config file which is stored on the local computer.

The screenshot shows a software window titled 'Imaging Reader 0.9.28'. The main content area is titled 'Mission Creation - Step 4/4 : Product and processing options'. Under the heading 'Workflow type', there are three radio buttons: 'Predefined' (which is selected), 'Remote config', and 'Local config file'. Below this, there are two input fields. The first is labeled 'User reflectance file (optional)' and the second is 'Reflectance file (optional)'. Each input field has a 'Clear' button to its right. At the bottom of the window, there are four buttons: 'Previous', 'Next', 'Finish', and 'Cancel'.

Figure 44 Product and processing options

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Optionally two files can be uploaded:

- **User reflectance file:** a list of image names or image numbers which are suitable for the picking of spectral reference panels. File format: no header text file, only one column with the image number or image name (excl. file extension).
- **Reflectance file:** Picking reflectance panels on images can be very time consuming. In case a previous run with the same mission data was already performed, the resulting picking file can be uploaded to avoid repicking of the same images.

Creating new mission

By clicking on Finish, all mission data is stored and the quality check will be performed before uploading the data to the cloud. If you don't see any problems with the quality checks you can go to the processing tab to continue.

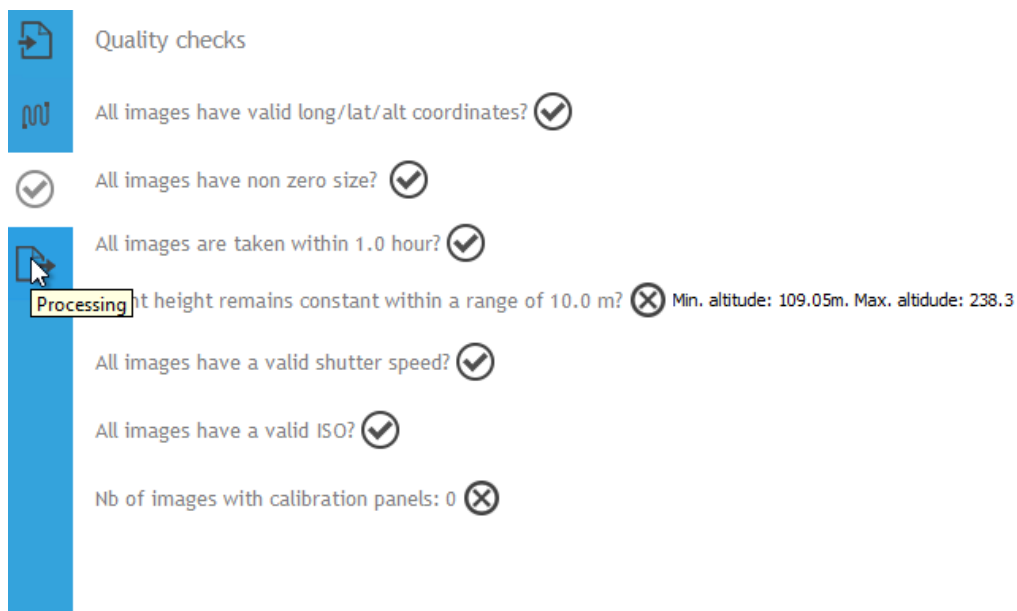


Figure 45 A list of quality checks. Positive and negative results are immediately visible.

Either press on Start to start uploading, or return and press Finish again to store any change. Note: in case you want to remove a queued mission, you can by using the right mouse button.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

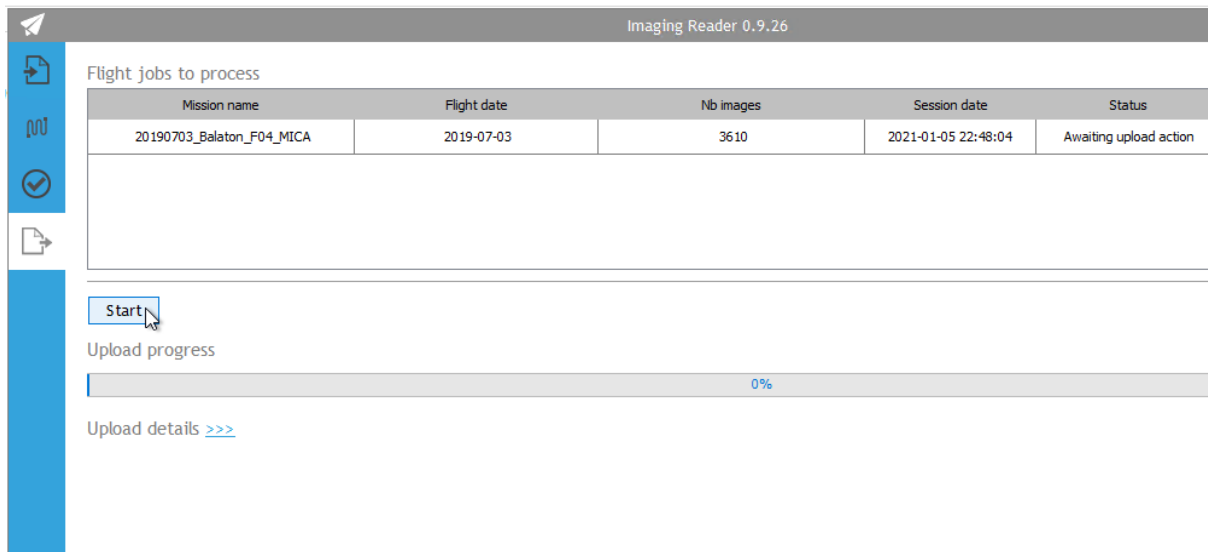


Figure 46 Starting the upload of the mission and drone data for data processing

Progress can be followed via the Upload details screen:

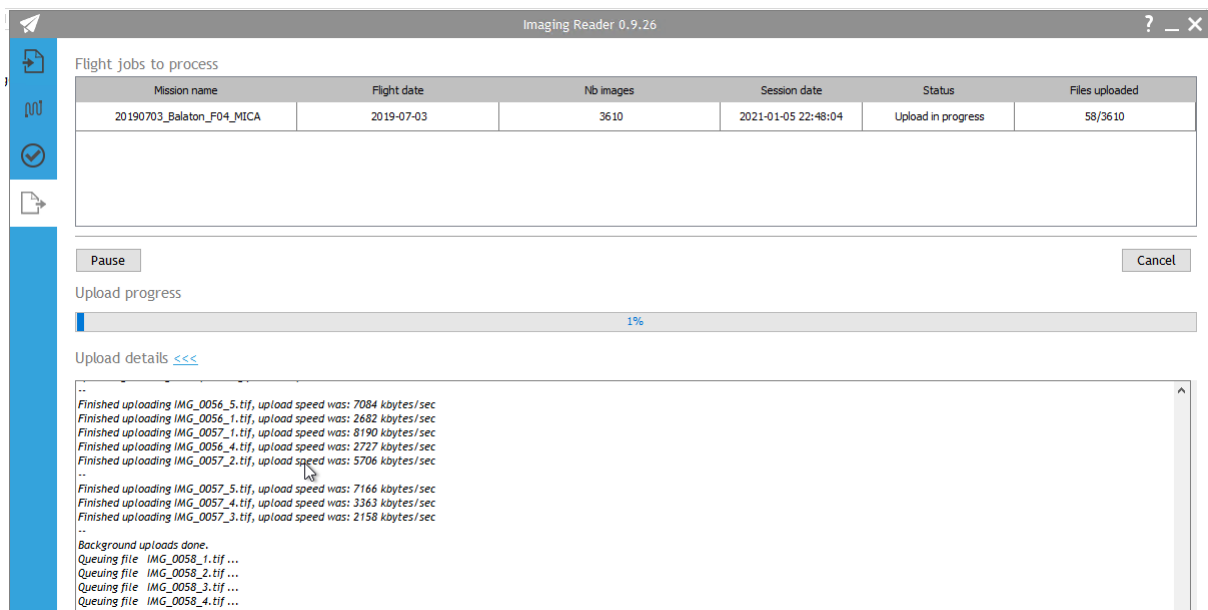


Figure 47 Progress follow-up.

System maintenance

- The DJI Phantom4 Pro maintenance guidelines are applicable.
- The Micasense camera maintenance guidelines are applicable.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.5 iSPEX 2

System description

iSPEX 2 is a smartphone add-on that turns the smartphone camera into a spectropolarimeter using an add-on mounted onto the smartphone. A grating projects a spectrum of incoming light onto the smartphone camera. This spectrum is modulated by a highly chromatic retarder to include dark bands that contain information on the linear polarisation of the incoming light. This provides a full linear polarimetric and spectrometric measurement.

The iSPEX 2 add-on consists of three parts, as shown in Figure 48. First there is a universal optical tube, containing polarisation optics and grating (center in the exploded view). Second, there is a universal clip to clamp iSPEX 2 onto a smartphone (left). Finally, there is a backplate (right), tailored to a specific smartphone model, to centre the iSPEX 2 in front of the camera. An in-depth description of the design and fabrication of iSPEX 2 is given in Burggraaf et al. (2020).

Due to the ubiquity of smartphones iSPEX 2 will allow anyone to become a citizen scientist and perform their own measurements of air quality (through aerosol optical depth) and water quality (through water colour measurements).



Figure 48 3D model of the iSPEX 2 add-on mounted on a smartphone. Left: full add-on. Right: exploded view.

System set-up/Installation

The iSPEX 2 add-on is assembled by combining the optical tube, smartphone clip, and the backplate. These simply click into place. When sliding the backplate onto the smartphone, iSPEX 2 is automatically placed in front of the camera. The associated smartphone app will guide the user through this installation process.

While iSPEX 2 can be used without any software it is preferably used with the iSPEX 2 app developed by DDQ and Leiden University. This app is made available for iOS and Android and captures background information, calibration options, measurement protocols, and data processing capabilities.

Since it is a completely passive add-on, iSPEX 2 does not require any power, connections, or communications other than those required by the smartphone itself. The iSPEX 2 app uses an internet

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

connection (Wi-Fi or mobile data) to communicate with the MONOCLE back-end either immediately or asynchronously such that data can be obtained off-line and uploaded later.

Data gathering

The app (smartphone) collects individual images (RAW/DNG format) along with relevant metadata. The user is guided through the steps in the iSPEX 2 app. For early testing and expert calibration we are use the SPECTACLE app which is currently available on the MONOCLE Github repository.

The iSPEX 2 app guides the user through the following measurement protocols:

1. Aerosol optical depth (AOD).
 - a. The user is instructed to mount iSPEX 2 on the smartphone.
 - b. If necessary, calibration measurements (spectral response, wavelength, flat-field) may be done.
 - c. The user is guided to orient themselves towards the principal plane.
 - d. The user is instructed to move the smartphone along the principal plane, with the app automatically taking exposure at pre-determined angles.
 - e. Optional measurements (for future upgrades) include observations along the solar aureole, almucantar, or horizon.
2. Remote-sensing reflectance (R_{rs}).
 - a. The user is instructed to mount iSPEX 2 on the smartphone.
 - b. If necessary, calibration measurements (spectral response, wavelength, flat-field) may be done.
 - c. The user is guided to orient themselves 135 degrees away from the solar azimuth. The user can choose whether this is clockwise or counterclockwise, depending on viewing conditions.
 - d. The user is instructed to orient the smartphone at a 40 degree angle from nadir.
 - e. The user is instructed to hold a grey card, flat, in front of the camera. An exposure is taken.
 - f. The user is instructed to remove the grey card, so the camera faces the water. An exposure is taken.
 - g. The user is instructed to orient the smartphone at 40 degrees from zenith. An exposure is taken.
3. Free mode.
 - a. The user is instructed to mount iSPEX 2 on the smartphone.
 - b. Any number of exposures may be taken by the user. The app provides metadata including exposure settings and camera orientation.

Data check (data reduction)

Basic checks are performed on the smartphone. This includes detecting poor positioning of the add-on, over- or underexposed images. The user may provide additional feedback regarding viewing conditions and image quality.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Data upload

Unless otherwise specified in the app settings, the RAW images are cropped to reduce the file size before transfer. This typically reduces them from 10-30 MB (depending on the device) to ideally <5 MB per image.

Once data have been collected, reduced, and quality checked, they are (asynchronously) sent through the Parse server mobile back-end (hosted on a Linux server). This back-end provides further processing capabilities, including scientific analysis, and forwards the data and results to the SOS portal.

A preliminary result is shown to the user to avoid long waiting/processing times.

System maintenance

Whereas the App and backend software require maintenance, the sensor operator only needs to keep the sensor attachment free of dust and grime and follow the calibration protocols provided to maintain performance of the sensor system. New backplate designs to accommodate future smartphone models can be created by the community as the base designs will be published.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.6 KdUINO (KdUSTICK and KdUMOD)

System description

KdUINO is a Do-It-Yourself moored instrument that measures the diffuse attenuation coefficient (K_d). The purpose of that is to assess the water transparency, a critical parameter to know the environmental status of water bodies, strongly affected by water quality-related components (such as phytoplankton, other organic matter and sediment). It is based on an array of quasi-digital sensors (light to frequency converters) that estimate light intensity at different depths.

In MONOCLE, the original KdUINO has evolved into a KdUSTICK and a KdUMOD (Figure 49) for low and medium-cost water transparency observations, respectively, in a portable package that can be deployed for the duration of a battery charge. KdUSTICK obtains light measurements at different depths (near the surface) to provide the broad-spectrum diffuse attenuation coefficient (K_d). KdUMOD is built as a versatile modular system. Each module placed at different depth has sensors for multispectral light measurements and temperature.

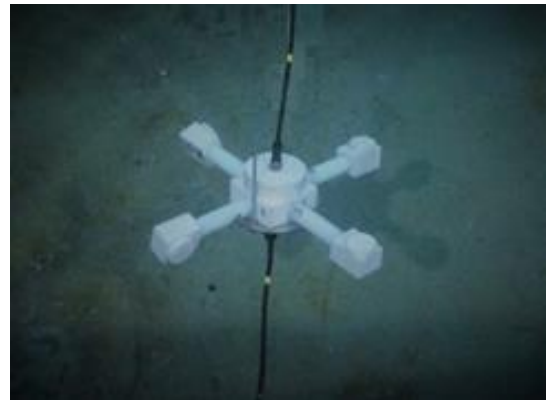


Figure 49 KdUSTICK (left) and KdUMOD (right) in testing environments

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

System set-up/installation

KdUSTICK

Hardware components

The hardware components of the KdUSTICK are:

- Microcontroller LoPy4 MicroPython Dev. Board (Espressif Esp32 Chipset)
- Pytrack sensor shield (accelerometer, GPS)
- MicroSD card
- IoT antenna (868Mhz / 915Mhz)
- Lithium Polymer (LiPo) batteries
- TCS34725 light sensors (OPT101 light sensor in an annular shape in the new version, in progress)
- Polyvinyl chloride (PVC) tube and bungs

The microcontroller is connected to an expansion board with the GPS, accelerometer, microSD card and deep sleep mode function. It uses the I2C bus to communicate with light sensors.

Software/ code

The microcontroller needs to have the following software and code installed:

- Integrated Development Environment (IDE) like Visual Studio or Atom
- Pymakr extension installed in the IDE.
- MicroPython code: <https://git.csic.es/kduino/kdustick>

List firmware versions:

- Pycom Firmware v1.20.2.r1

System set-up

1. Upload the CSIC Gitlab MicroPython code on the microcontroller
2. Plug-in the power connection from LiPo batteries
3. Place the KdUSTICK with all light sensors inside the PVC tube
4. Close the tube using the bungs

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

KdUMOD

Hardware components

The hardware components of the KdUMOD are:

1.- For the surface buoy transmitting data:

- Microcontroller LoPy4 MicroPython Dev. Board (Espressif Esp32 Chipset)
- Pytrack sensor shield (accelerometer, GPS)
- MicroSD card
- IoT antenna (868Mhz / 915Mhz)
- Lithium Polymer (LiPo) batteries
- Buoy structure and wires

2.- For each independent light sensor module:

- Esp8266 Dev. Board (Adafruit) + RTC and SD module
- MicroSD card
- AS7262 multispectral light sensors
- Temperature sensor
- Polyamide structure and wires

The buoy microcontroller gets data from sensors placed in the modules through serial port communication.

Software/ code

The microcontroller needs to have the following software and code installed:

- Integrated Development Environment (IDE) like Visual Studio or Atom. with
- Pymakr extension installed in the IDE.
- MicroPython code: <https://git.csic.es/kduino/kdumod>

List firmware versions:

- Pycom Firmware v1.20.2.r1
- MicroPython 1.13

System set-up

1. Upload the CSIC Gitlab MicroPhyton code on the microcontrollers
2. Place the Lopy4 microcontroller in the buoy structure
3. Place the ESP8266 microcontroller in the modules structures and connect light and temperature sensors
4. Connect all the modules between them, and finally with the buoy
5. Plug-in the power connection from LiPo batteries in the buoy
6. Close the buoy structure and the modules

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Bluetooth will connect KdUSTICK and KdUMOD to the mobile application (in progress), and it will facilitate the system set-up.

Both can transmit data in real-time using the Internet of Things (IoT) networks (LoRaWan and Sigfox). The data are first transmitted to CSIC servers, and from there to a SOS back-end. The KdUINO products also store data on a local SD drive.

System check

The device has a LED as a system check warning the user if everything is fine.

- If something goes wrong (e.g., the SD card is improperly seated) you will see the red LED flashing intermittently.
- If everything is fine the LED light indicates the following status:
 - Start. Green LED during 3 seconds
 - Get latitude and longitude from GPS. Yellow LED during 3 seconds
 - Send data using IoT networks. Blue LED during 3 seconds

Field calibration

K_d is computed from relative light intensity measurements from sensors placed at different depths in the water column. It is not necessary to know the light intensity at each point in the water column, but only the relative decrease in energy received between two depths. In a multi-sensor system this means that all sensors must be well inter-calibrated, i.e. providing precisely the same frequency value when measuring the same light intensity.

However, due to an absolute frequency tolerance of x per cent from the light sensor manufacturing procedure, different sensors under the same measuring conditions provide different measurement results by default.

In the case of KdUSTICK using light sensor TCS34725, the absolute tolerance frequency is 20%.

In the case of KdUMOD using light sensor AS7262, the absolute tolerance frequency is 24%.

In order to compensate such differences, sensors must be calibrated. The calibration consists of measuring the same light intensity during the same period of time simultaneously using all the sensors (Figure 50). Then, compensate the difference as follows: the sensor with the highest measurement value is taken as the reference sensor. A multiplying factor is then computed for the other sensors to get the same intensity value as the one obtained by the reference sensor under the same conditions.



Figure 50 Calibration of light sensors measuring the same light intensity

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Data gathering

KdUSTICK

Before we start doing measurements, we will need to prepare the KdUSTICK, check its operation and calibrate the sensors.

It is optimal to measure under solar zenith angles $< 20^\circ$ (the sun is overhead), and avoiding shading from other sensors or platforms. The KdUSTICK must be perpendicular to the water surface (Figure 51).

The KdUSTICK should ideally be kept in place for at least 1 hour. All data are saved in local storage while only processed data are transferred via the internet in real-time.



Figure 51 KdUSTICK measuring in the correct position

KdUMOD

The KdUMOD modules require assembly and attachment to the buoy system (Figure 52).

The KdUMOD can be deployed for long periods (days or weeks, depending on battery life). KdUMOD will then measures when the sun is around its highest point, to avoid shading and to capture the highest signal (not considering cloud cover). The system then enters deep sleep mode to save battery power. All data records are saved in local storage while only processed data are transferred via internet in real-time.

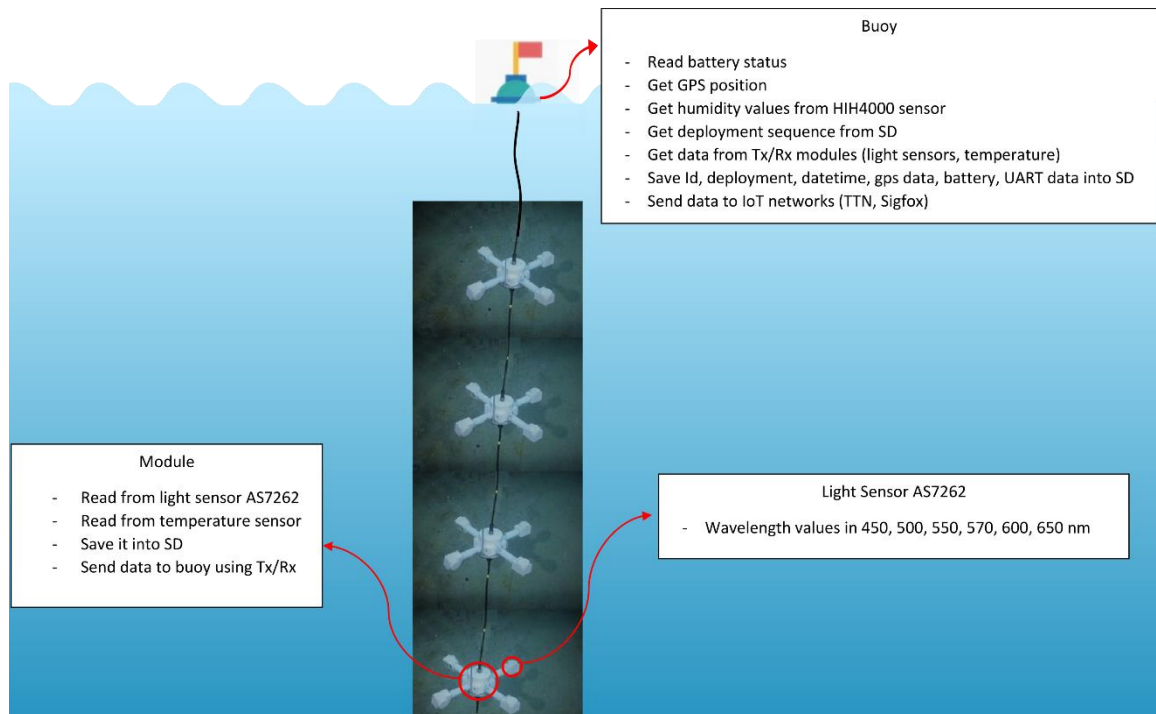


Figure 52 Schematic of KdUMOD

Data check

The KdUSTICK and KdUMOD can process data at the time of data acquisition. The coefficient of determination of K_d is calculated and sent in real-time to a back-end server to verify data quality.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

In the case of the KdUSTICK, the accelerometer on-board allows the calculation of the correct position of the instrument and the angle of deployment is included in the metadata.

Data upload

Once data are collected and quality checked they are transferred via the internet to the data backend server (at CSIC). From this server we manage further data formatting and standardisation for wider distribution through interoperable data services.

System maintenance

Maintenance efforts are required if the KdUSTICK or KdUMOD are on long deployments (mainly KdUMOD). In this case, the instruments require cleaning, specifically the optical parts to avoid fouling. Batteries will require replacing once they have discharged. Calibration should be repeated frequently as discussed above.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

5.7 FreshWater Watch (FWW)

System description

FreshWater Watch (FWW) is an integrated and flexible citizen science programme run with a specific focus on water quality monitoring. The programme was designed to explore the effects of river restoration, catchment management practices and land use change on the chemical, biological and optical characteristics of freshwater ecosystems, including lakes, ponds, streams, rivers, canals, and wetlands. FWW was established in 2012 and has now evolved into a cost-effective water quality monitoring approach that includes a multilanguage data acquisition and engagement smartphone app and online hub. The data hub (<https://freshwaterwatch.thewaterhub.org/>) not only provides the means to carry out basic data analysis and gain feedback, but also gives access to learning resources and facilitates the development of a global volunteer community.

The data acquisition approach includes measurements standard measurements for all projects and optional measurements that can be selected by the local project leader. The standard measurements were chosen to represent those parameters that are commonly monitored for statutory purposes and support local, national and international monitoring initiatives, and designed to be appropriate for citizen scientists. These parameters included turbidity, nutrient concentrations, presence/absence of bankside vegetation, visible pollution, pollution sources, algal blooms and common aquatic fauna. Optional measurements include microbiological, macroinvertebrates, specific conductance, various climate and land use fields, as well as additional chemical (dissolved oxygen, ammonium) and specific pollution focuses (macroplastics).

The standard kit includes instruments for the measurement of nephelometric turbidity (Secchi tube), dissolved nitrate and dissolved phosphate, together with colour charts, cuvette and sampling gloves (Figure 53). Observational parameters are requested during each site measurements using the app or online system. Currently FWW materials are available in the following languages: English, French, Portuguese, Spanish, Swedish, Kiswahili, Chinese (Mandarin).



Figure 53: Standard FWW sampling kit

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

System set-up/Installation

Sampling by citizen scientists is performed in a secure manner to gather a representative sample of the studied freshwater ecosystem and its surroundings. Safety guidelines include the use of proper footwear, protective gloves and knowledge of local risks.

Location and time of measurements are recorded on the FWW app. The bioavailable forms of nitrate ($\text{NO}_3\text{-N}$) and phosphate ($\text{PO}_4\text{-P}$) are determined using a standard 1.5ml sampling cuvette to allow for an accurate and consistent volume of sample. The nutrient-testing tubes (viable for one year) for $\text{NO}_3\text{-N}$ contain zinc reduce nitrate (NO_3^-) to nitrite (NO_2^-), N-(1-naphthyl)ethylenediamine dihydrochloride and sulfanilamide. The concentration of nitrite is then determined by colorimetric reaction following the Greiss method (Ellis et al. 2011; Strickland & Parsons, 1972). For $\text{PO}_4\text{-P}$ an inosine enzymatic reaction is used to colorimetrically determine dissolved phosphate concentrations (Berti et al., 1998).

Nephelometric turbidity is measured using a Secchi tube – a 0.5 metre plastic tube with a Secchi disc at the bottom. The tube has a graduated, non-linear scale of Nephelometric Turbidity Units (NTU) on the side. Measurements are based on the depth of the water at which the Secchi disc is no longer visible to the observer peering into the top of the tube. Volunteers are asked, at the same time, to assign the water colour to a yellow, brown, green or other.



Figure 54 Citizen scientists sampling for FWW measurements

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

Data gathering

The app (smartphone) allows users to record information about the measurements and observational information about the study site. Users are asked to take a photograph of the site that is used for analysis and validation. The direction and objective of the photograph follows a prescribed approach, depending on whether the study ecosystem is a lake or river. For rivers or streams, the photograph should face upstream and include as much of the following as possible:

- Some part of the water body and the immediate surrounding land use
- Water height with respect to some reference point (bridge, tree, boulder)
- Water colour
- Type of ground material (substrate) in and around the water body
- Bank vegetation cover and type
- Surrounding vegetation and habitats
- Visible pollution sources

Images along with relevant metadata are stored on the FWW database.

Data check (quality control)

All participating citizen scientists undergo a standard training protocol, provided online or in-situ (following a train the trainer approach). The online training video provides information on the correct use of the water quality sampling methodology and the platform and can be accessed at any time via the website or mobile app. Printed instructions are also provided with the FWW kits. Participants must take a quiz to demonstrate that they have watched and understood the video before they can upload any samples. In addition, Earthwatch provide ad-hoc face-to-face training both for participants and for project coordinators, following the 'train the trainer' model. This training has been shown to play an important role in volunteer retention, helping to ensure continuity of datasets (August et al, 2019).

Users are trained to check their data for common errors at the point of upload. Local project leaders have access to all data from local study sites and are directed to check data within one week of data collection, revisiting sites if necessary. Earthwatch perform a monthly review of all data submitted, triggering emails to volunteers requesting clarification where potential errors are detected.

Basic checks are performed on the smartphone. This includes detecting bad positioning of the add-on, over- or underexposed images, and specific problems that may be identified in the future. The user may provide additional feedback regarding viewing conditions, image quality, etc.

The FWW methodology has been designed to provide accurate, meaningful data on freshwater ecosystems while being simple for users who have no prior scientific understanding. The nutrient tests have been tested against laboratory tests in multiple scenarios by both professional and volunteer users (Biggs, et al. 2016, Loiseau et al. 2016). Secchi tubes have also been shown to give a good correlation with turbidity (Miguel-Chinchilla et al. 2019) and have been used successfully in multiple citizen science programs (Lottig et al. 2014). Project coordinators and volunteers are encouraged to repeat samples at 10% of sites in order to create redundancy in the dataset that can be used to check methodological consistency.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

In order to reduce errors at the data entry stage, the FWW app is designed to highlight any potential errors. For example, the geolocation is highlighted until it has been successfully logged by the participant, and incomplete datasets cannot be submitted. Once data is submitted, an internal model triggers a feedback message that summarises the conditions logged. This feedback message not only provides instantaneous basic interpretation of results to the user, but also acts as a prompt for users to check that data has been entered correctly and to edit any mistakes.

Post-sampling examination of data is carried out by volunteers, project coordinators, and by Earthwatch. By including complementary and overlapping variables within the methodology, common errors can easily be identified and highlighted using automated processes. For example, records that show both high turbidity and a 'colourless' water colour are flagged for review. Data tools within the online platform can also help to highlight errors. These tools include the instantaneous feedback messages described above, as well as comparative statistics showing differences between measurements within the same locale that are made available on the website.

System maintenance and open data access

The kit used for nutrients has an expiry date, but otherwise remains useful until it is used up. Earthwatch Europe maintain the App and data service, including online database and data portal. All datasets gathered in the MONOCLE project are available on an Earthwatch GeoServer instance (<https://geo.earthwatch.org.uk/geoserver/web/>). GeoServer is an open-source server for sharing geospatial data, which publishes data through open standards. FWW data and maps can be served in a variety of formats (both vector and raster) to standard clients such as web browsers and desktop GIS programs.

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

6. Exploitation and Dissemination

The information in this document has been tested and verified in the field and can be used as a guide by trainers and sensor operators. This document combines deployment information and protocols of multiple instruments which are useful to combine water quality observation and satellite calibration and validation. Most users will select sensors and platforms tailored to their specific needs. We encourage those users and programme managers to review the information on specific sensors which is made available through the MONOCLE website, which provides updated materials in addition to this collated overview, some of which are also tailored to specific expert and non-expert audiences. All data collected during the MONOCLE field campaigns, including sensor observation data, metadata, calibration data files and data processing pathways will be openly accessible through the MONOCLE data infrastructure (including data servers and an interactive web visualisation portal) as detailed in the Data Management Plan. This is an ongoing process throughout during sensor development after each planned field campaign.

7. Future activities/recommendations

This deliverable describes the operational protocols for the sensors and systems developed and tested in the MONOCLE project. This deliverable will be publicly available. Development of the sensors, platforms and (data) interfaces continues – to receive updates on these developments, the reader is encouraged to sign up for project updates through the website at <https://monocle-h2020.eu>

8. References

- August, T.A., West, S.E., Robson, H., Lyon, J., Huddart, J., Velasquez, L.F. and Thornhill, I., 2019. Citizen meets social science: predicting volunteer involvement in a global freshwater monitoring experiment. *Freshwater science*, 38(2), pp.321-331.
- Berti, G., Fossati, P., Tarengi, G., Musitelli, C. and Melzi d’Eril, G.V., Enzymatic colorimetric method for the determination of inorganic phosphorus in serum and urine. *Clinical Chemistry and Laboratory Medicine*, 1988;26(6):399-404.
- Brando, V., Lovell, J, King, E., Boadle, D., Scott, R., Schroeder, T. (2016) The Potential of Autonomous Ship-Borne Hyperspectral Radiometers for the Validation of Ocean Color Radiometry Data, *Remote Sensing*, 2016.
- Burggraaff, O., Perduijn, A.B., van Hek, R.F., Schmidt, N., Keller, C.U., Snik, F. (2020) A universal smartphone add-on for portable spectroscopy and polarimetry: iSPEX 2, *Micro-and Nanotechnology Sensors, Systems, and Applications XII* 11389, 113892K, <https://doi.org/10.1117/12.2558562>.
- Ellis PS, Shabani AMH, Gentle BS, McKelvie ID. Field measurement of nitrate in marine and estuarine waters with a flow analysis system utilizing on-line zinc reduction. *Talanta* [Internet]. 2011 [cited 2017 Apr 26];84(1):98–103. Available from: <http://www.sciencedirect.com/science/article/pii/S0039914010010180>
- CEOS. A. G. Dekker and N. Pinnel, editors. (2017). Feasibility study for an aquatic ecosystem Earth observing system. Report v. 1.1. Committee on Earth Observation Satellites (CEOS) and

Project	MONOCLE H2020 (grant 776480)	Start / Duration	1 February 2018/ 48 Months
Dissemination	PUBLIC	Nature	REPORT
Date	09 Feb 2021	Version	1.0

- Commonwealth Scientific and Industrial Research Organization (CSIRO). CSIRO, Canberra, ACT, Australia.
- Groetsch, P.M.; Gege, P.; Simis, S.G.; Eleveld, M.A.; Peters, S.W. (2018). Validation of a spectral correction procedure for sun and sky reflections in above-water reflectance measurements. *Opt. Express* 2017, 25, A742–A761.
- Han Y.G., Jung S.H. & Kwon O. (2017). How to utilize vegetation survey using drone image and image analysis software. *Journal of Ecology and Environment*, Vol. 41, No.18.
- Hommersom, A., Kratzer, S., Laanen, M. L., Ansko, I., Ligi, M., Bresciani, M., ... Peters, S. W. M. (2012). Intercomparison in the field between the new WISP-3 and other radiometers (TriOS Ramses, ASD FieldSpec, and TACCS). *Journal of Applied Remote Sensing*, 6, 06315-1-06315-21. doi: 10.1117/1.JRS.6.063615
- Lee, Z.P.; Ahn, Y.H.; Mobley, C.; Arnone, R. Removal of surface-reflected light for the measurement of remote-sensing reflectance from an above-surface platform. *Opt. Express* 2010, 18, 26313–26324.
- Lottig, N. R., T. Wagner, E. Norton Henry, K. Spence Cheruvellil, K. E. Webster, J. A. Downing, and C. A. Stow. 2014. Long-Term Citizen-Collected Data Reveal Geographical Patterns and Temporal Trends in Lake Water Clarity. *PLoS ONE* 9:e95769.
- Miguel-Chinchilla, L., Heasley, E., Loiselle, S. and Thornhill, I., 2019. Local and landscape influences on turbidity in urban streams: a global approach using citizen scientists. *Freshwater Science*, 38(2), pp.303-320.
- Mobley, C. D. (1999). Estimation of the remote-sensing reflectance from above-surface measurements. *Appl. Opt.* 38(36), 7442–7455.
<http://dx.doi.org/10.1364/AO.38.007442.APOPAI0003-6935>
- Riddick, C.A.L., et al. (2018). D4.1 Report on performance criteria for field testing. Deliverable report of project H2020 MONOCLE (grant 776480), doi: 10.5281/zenodo.1492178
- Strackx, G. (2019). 3D prints integration MicaSense RedEdge under DJI PH4 pro. Zenodo.
<http://doi.org/10.5281/zenodo.2578108>
- Strickland J, Parsons T. A practical handbook of seawater analysis. 1972 [cited 2017 Apr 26]; Available from: http://epic.awi.de/39262/1/Strickland-Parsons_1972.pdf
- Tilstone, G. and G. Moore, eds. (2002). REVAMP Regional Validation of MERIS Chlorophyll products in North Sea coastal waters: Protocols document.
- Wernand M.R. Guidelines for (Ship-Borne) Auto-Monitoring of Coastal and Ocean Colour. (2002) In: Ackleson S.G., Trees C., editors. *Proceedings of Ocean Optics XVI*; Santa Fe, NM, USA. 18– 22
<http://melia.nioz.nl/phptoweb/colors/documentation/colours38.htm>
- Wright, A, Simis, S.G.H. (2020). Construction of the Solar-tracking Radiometry Platform (So-Rad). doi: 10.5281/zenodo.4485805.
- Zibordi, G., Holben, B., Slutsker, I., Giles, D., D’Alimonte, D., Melin, F., Berthon, J.-F., Vandemark, D., Feng, H., Schuster, G., Fabbri, B. E., Kaitala, S., and Seppala, J. (2009). AERONET-OC: a network for the validation of Ocean Color primary radiometric products, *J. Atmos. Oc. Technol.*, 26, 1634–1651.