USING AUVS FOR MEASURING SEDIMENTATION PROCESSES IN RESERVOIRS

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UNDERWATER INSPECTION: TODAY'S CHALLENGES

MARITIME OPERATIONS REQUIRE REGULAR INSPECTION

Biofouling on ship hulls

€5,3m per ship per year in potential fuel over consumption due to biofouling

Structural integrity of critical infrastructure

1500km of quay wall in Netherlands alone needs monitoring

Security risks of foreign incoming vessels

60.000 vessels call EU ports annually, only 0,9% can be inspected

FIRST FULLY AUTONOMOUS UNDERWATER INSPECTION SYSTEM

Data collection

Fully **autonomous data collection** via underwater robot

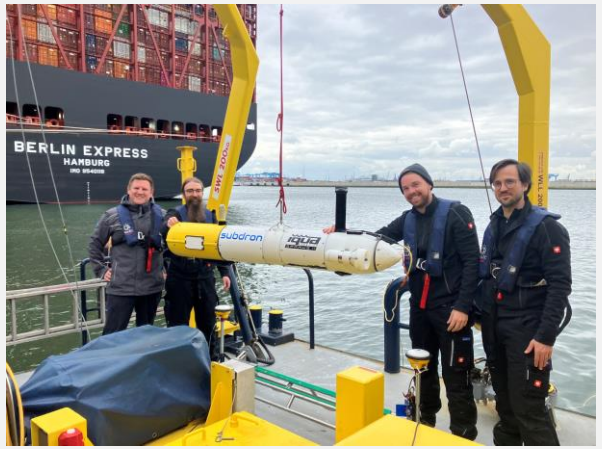
Data processing

Data feed to **subdron-cloud**, where Machine Learning methods **process** and **label** the data

Visualization

Subviz web-based tool will provide **visualization** and reports of the data collected

VALUE PROPOSITION: FIRST AUTONOMOUS UNDERWATER INSPECTION



EFFICIENCY AND IMPACT

Reduction of **GHG**
833m of tons globally

5x faster inspection time

50% lower cost to inspect

SAFETY AND RELIABILITY

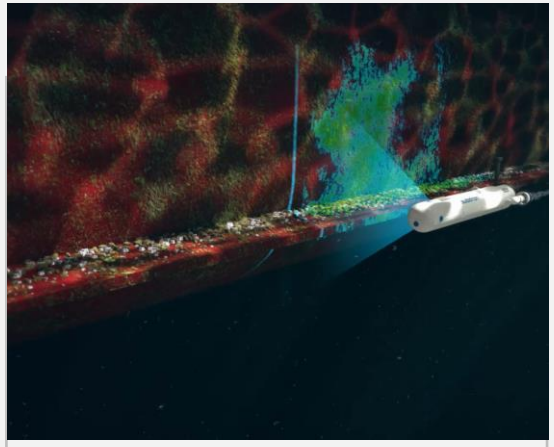
Less human intervention in challenging environments

High quality results in low visibility conditions

Predictive maintenance possible for the first time

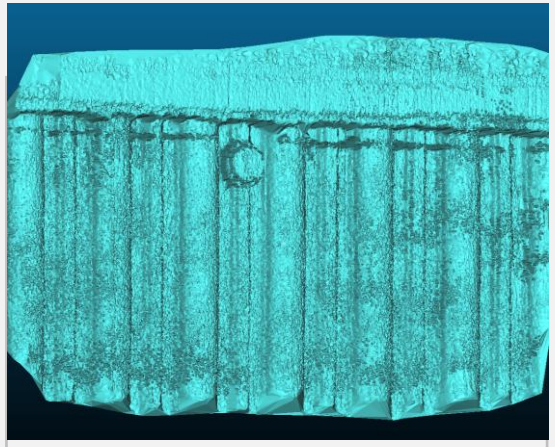
VALUE FOR THE END USERS

Inspection Companies and Ship or Port Operators



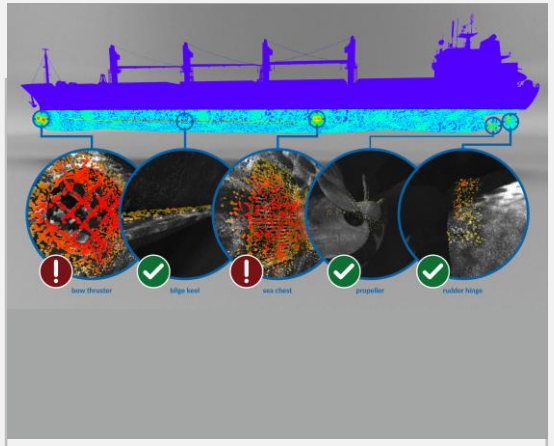
Full autonomy and **increase** number of vessel inspection **per year**

No tether involved



Continuous asset **mapping**

High accurate 3D point cloud and 3D model



Automatic detection and **classification** of **biofouling**

Reduce fuel consumption and **GHG emission**

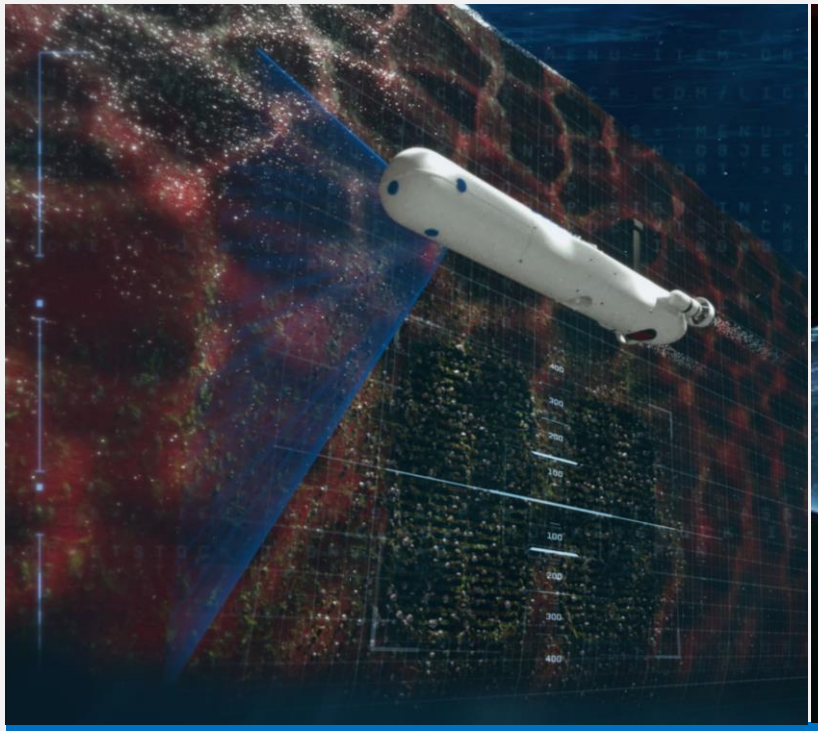
Advantages for the customer :

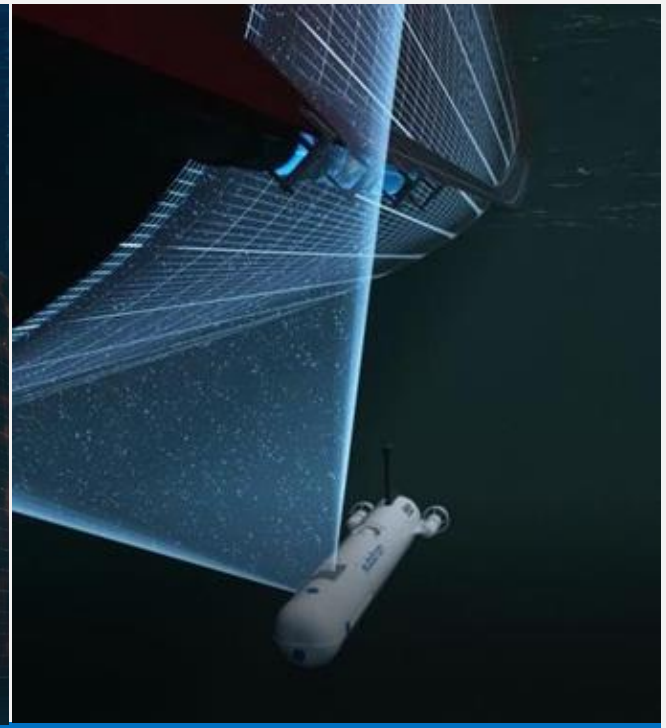
- Price leadership : up to 50% cost reduction
- Increased profitability
- Unprecedented level of service through more frequent inspections + 3D reconstructions

Benefits for the end users :

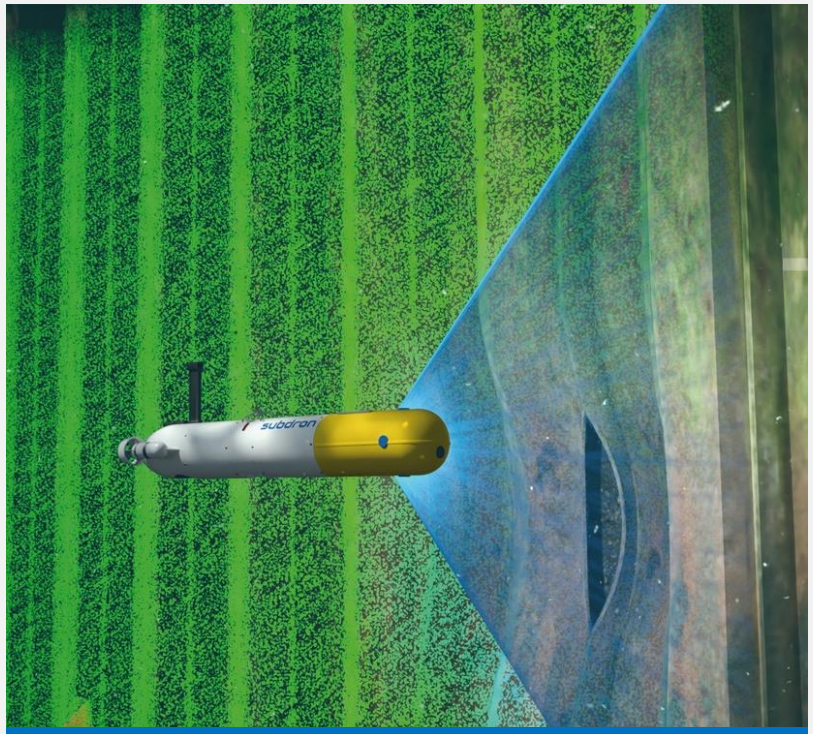
- Fuel consumption reduction of €4m /year /ship
- Reduction of emissions related cost of €1m /year /ship
- Predictive maintenance
- Less downtime

TWO MAIN SOLUTIONS





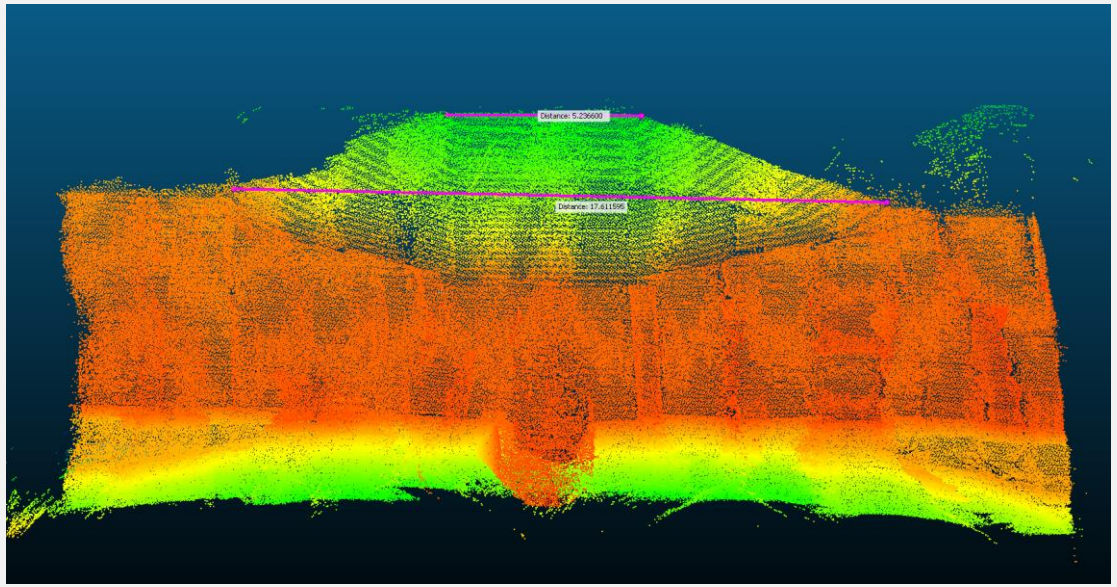
v.dron
maps ship hulls for biofouling and anomalies

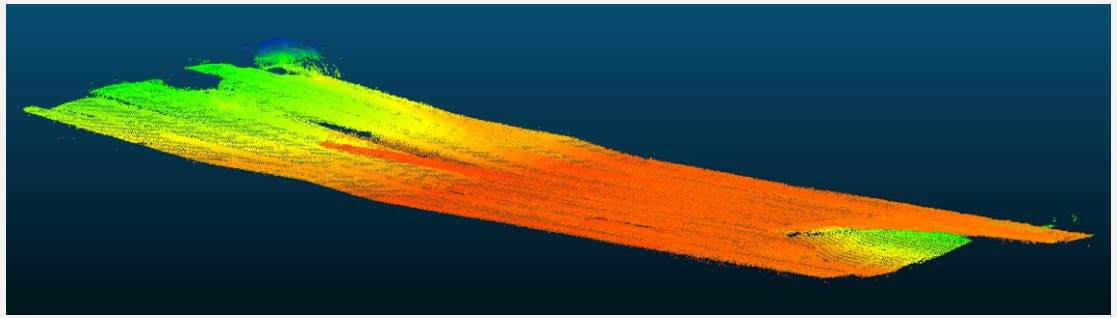


p.dron
maps port infrastructure

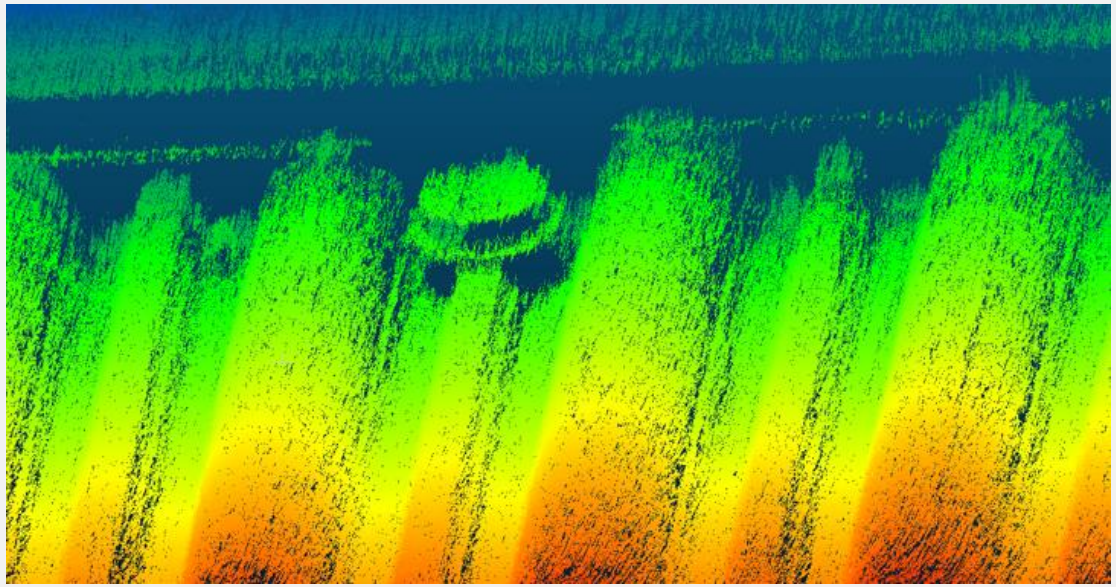
PREVIOUS RESULTS

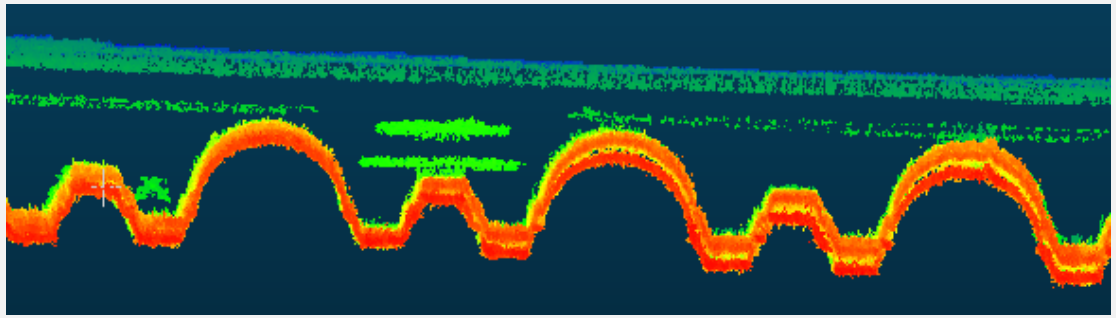
Ship Inspection - v.dron





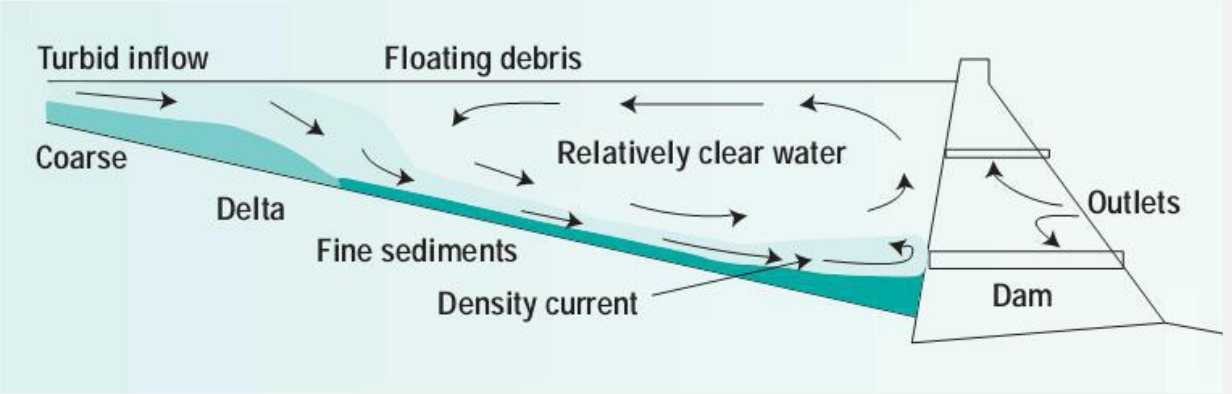
Port Inspection - p.dron





THE CHALLENGE OF SEDIMENT ACCUMULATION

- Hydropower-generated energy is reliability and flexibility.
- Energy production
  - 31,5% United States of America,
  - 29,0% European Union.
- By 2050 the capacity loss will be 26%
  - Current loss is 16%
- Sediments accumulation:
  - Reduce life span and capacity of a reservoir,
  - Damage water intakes and reduce power production,
  - Block water intakes,
  - Forcing Re-designs of the infrastructure.



SOURCE: Palmieri et al, 2003.

HOW IT'S CURRENTLY DONE

- Currently are used
  - Surface vessels (manned or unmanned)
    - MBES,
    - Sediment Sampler.
  - Moored sensors
    - ADCP sensor,
    - Sediment trap.

- These measurements may not be enough:
  - detailed around the intake and outlets,
  - to measure the evolution of gravity currents,
  - to capture the interaction of movable reservoir ground and the turbidity current.

EchoBoat ASV
Source: Aspectsurveys

Enviro Sensor
Source: Aspectsurveys

Marine Sensor
Source: Aspectsurveys

AUV FOR SEDIMENTATION MEASUREMENTS

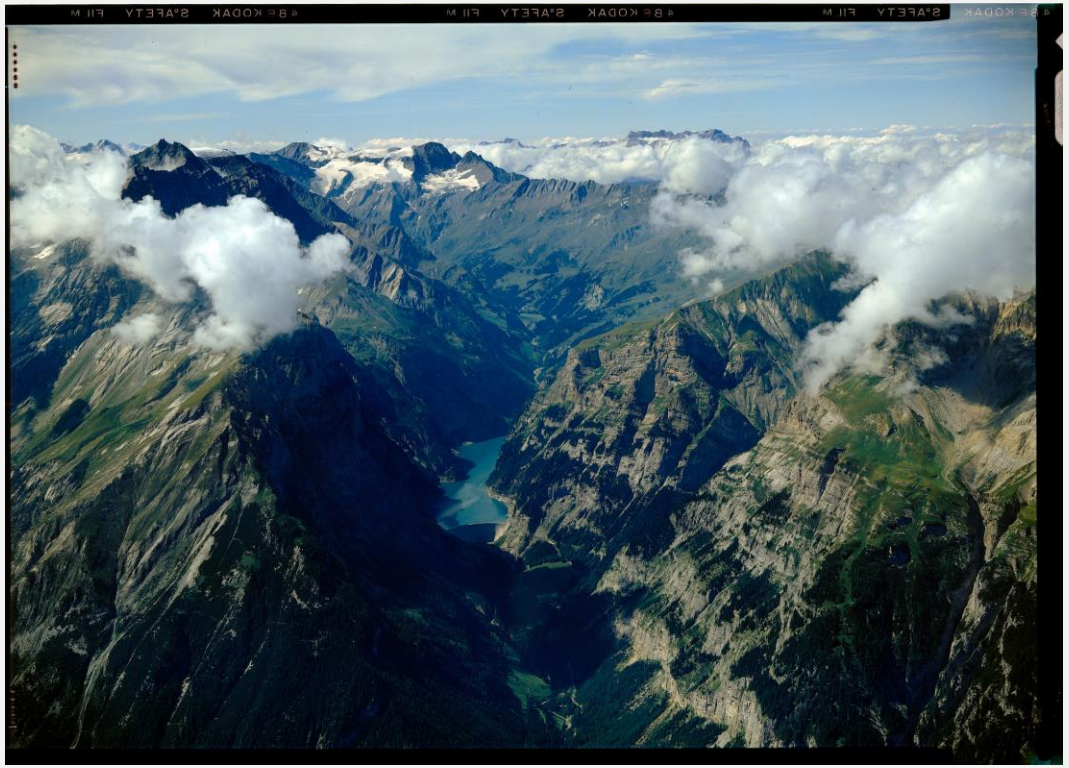
- Advantages AUV:
  - Sensor closer to the target areas -> Higher resolution
  - Constant measurements along the water column
- Challenges
  - No global positioning
  - Reduced communications underwater

- Subdron and ETH Zurich will characterize the environment:
  - ADCP (Acoustic Doppler Current Profiler) measurements:
    - Signal-to-Noise Ratio (SNR) to measure Suspended Sediment Concentration (SSC).
  - High-resolution bathymetry obtained with MBES measurement:
    - Calculate sediment accumulation map,
    - Study the interaction and erosional/depositional processes.

MISSION ENVIRONMENT

Gigerwaldsee – Switzerland

- Built between 1973 and 1975 in the canton of St. Gallen, Switzerland,
- Sedimentation has been an ongoing issue at Gigerwald reservoir for years, especially close to the dam,
- Average annual sedimentation volume of 60,000 m^3 and an accumulated storage volume loss of 5% since start of operation[1],
- Rising at an average annual rate of around 0.5 m between 2003 and 2023,
- The sediment level at the dam reached the intake in 2020[2].
- During winter 2024 until Summer2025 adaptation works to rise the low-level outlet and the headrace tunnel 20m and 25m.



Aerial view of Gigerwald reservoir in October 1983 (Comet Photo AG / ETH Library Zurich, Image Archive / Com_FC27-0016-002.tif / CC BY-SA 4.0)

[1] Müller & De Cesare (2009)

2 Schmid (2024)

MISSION PREPARATION - EQUIPMENT

AUV - SPARUS II AUV (IQUA Robotics)

- GNSS Antenna with RTK
- USBL receiver
- Sound Velocity Sensor
- MBES Imagenex Delta-T 260 KHz
- Pressure sensor
- DVL with ADCP Capabilities

Surface Boat

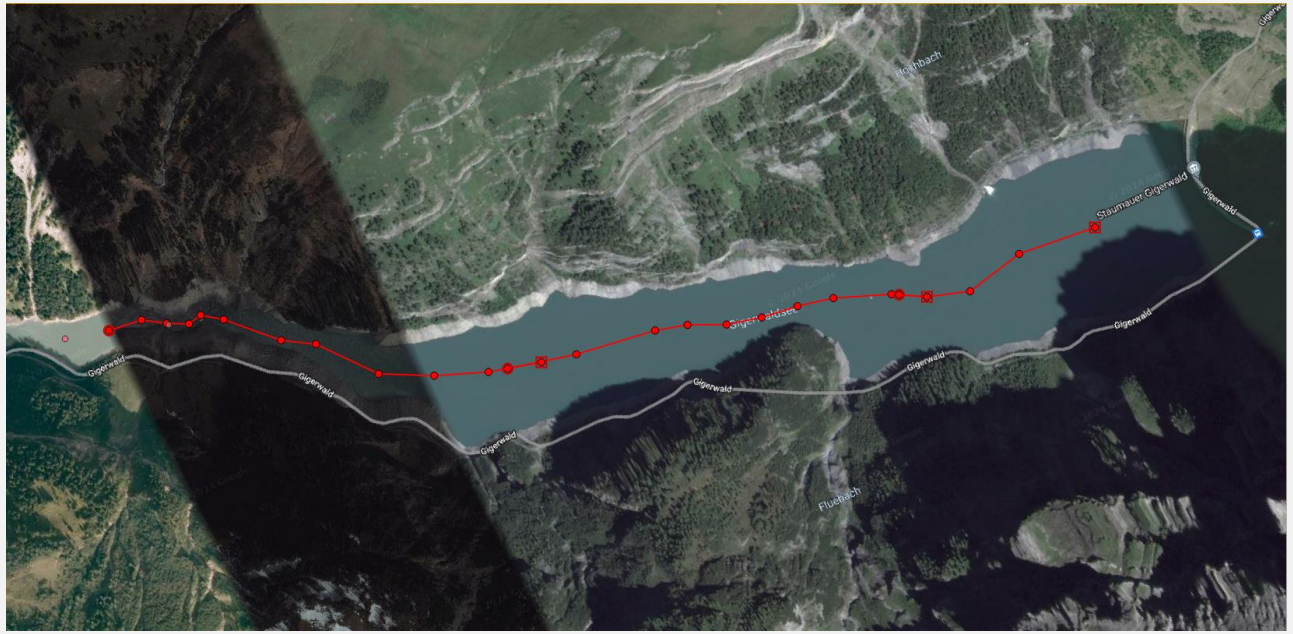
- GNSS Antenna with RTK
- USBL transceiver
- Sediment Sampler
  - Van Dorn bottle sampler

MISSION PREPARATION

- Thalweg following trajectory:
  - Altitude of 15-20m
  - Speed 0,4 m/s
  - Depth 15m to 80m
  - Tracks 1 km

- Vertical Sampling (AUV and Sampler):
  - 5-10 vertical samples,
  - from surface to 15 m altitude

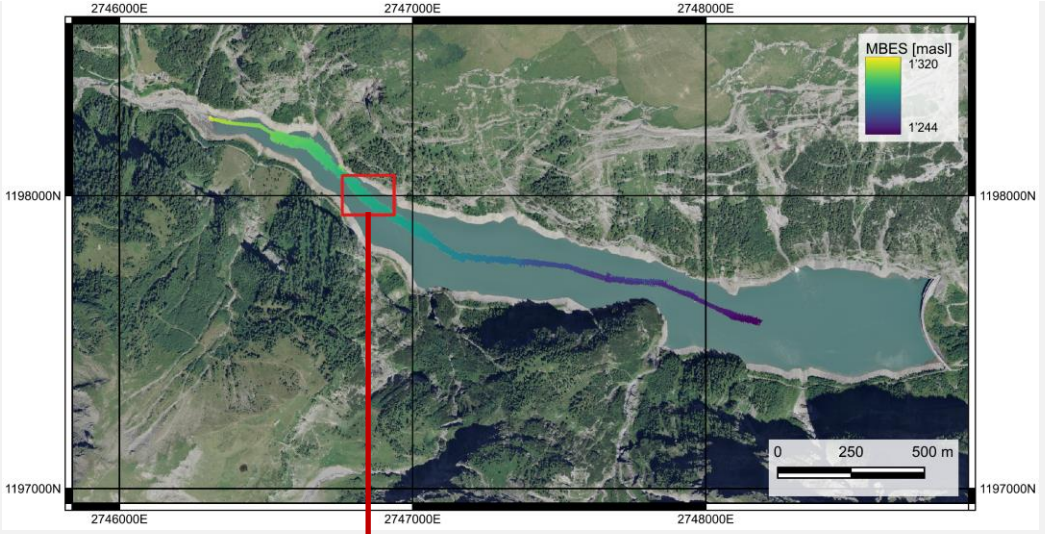
- Data Collected:
  - MBES
  - ADCP

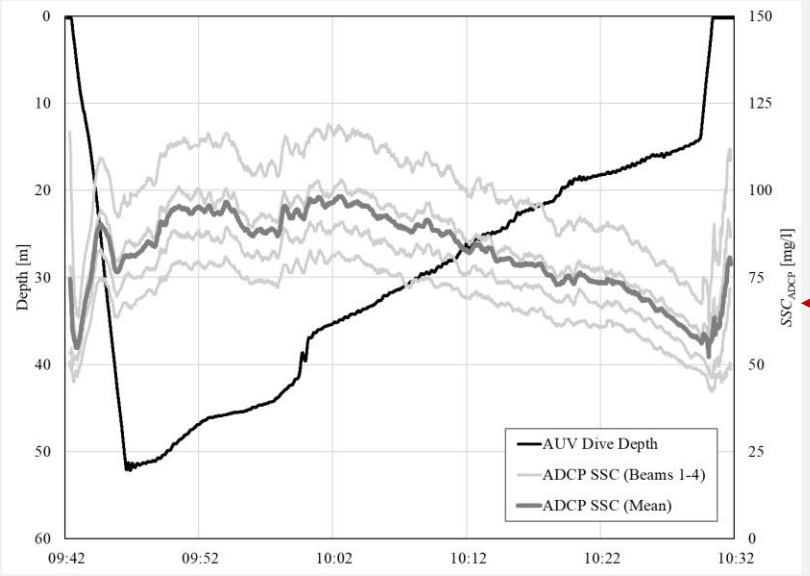


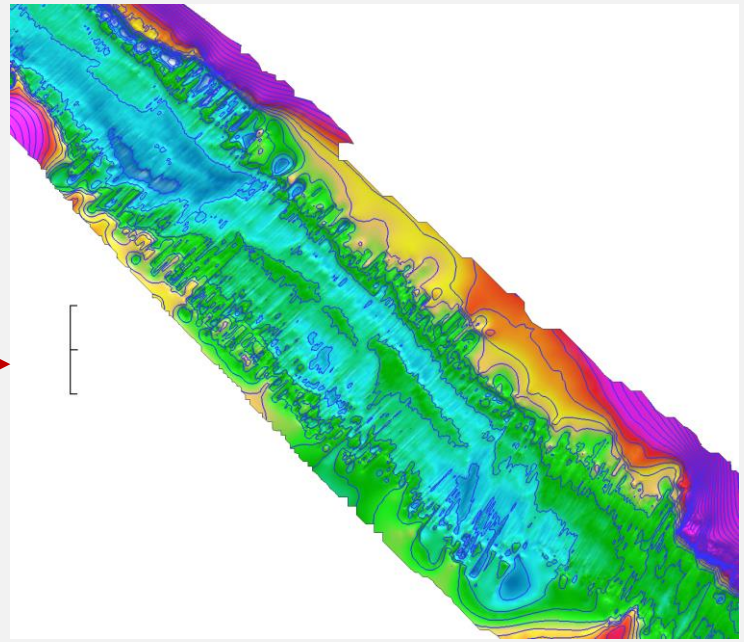
PRELIMINARY RESULTS

Data Colleted

- 2 Campaigns (June & July)
- Thalweg following trajectory
  - 6 km track
  - Resolution between 0,05m – 0,1m
- Vertical Sampling
  - 10 vertical samples in strategic locations
  - vertical speed of 0.20 m/s







CONCLUSIONS

- AUVs have great potential to complement standard approaches
  - measuring sedimentation processes in reservoirs,
  - increase spatial and temporal data resolution.
- Two field campaigns were successfully made in the Gigerwarld Alpine reservoir,
  - Gigerwald reservoirs highly impacted by sedimentation.
- Preliminary results provide insights into the measurement capabilities
  - AUVs in terms of high-resolution bathymetric scans and
  - Measurement of suspended sediment concentration in the water column.

FUTURE WORK

- Analysis of the data collected and comparison of multiple campaigns.

- During the two campaigns different aspects need to be improved on the AUV
  - Localization system for the surface boat
  - Stable positioning
  - Subdron Relative Object Navigation (RON) could be applied for thalweg following.
  - Inclusion of Turbidity Sensor or Laser In-Situ Scattering and Transmissometry (LISST) sensor

- Mapping of the Sedimentation around the Water Intake
  - Adaptation of RON to map the surroundings of the Water Intake

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