From above and below: Habitat mapping of an alpine lake in Austria

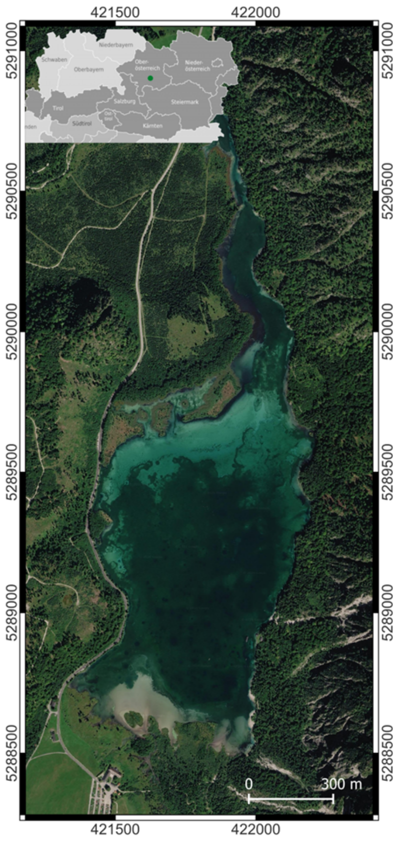
Hydrographentag 2026

Annika L. Walter, M.Sc.; Lucas Dammert, M.Sc.; Ellen Heffner, M. Sc.

Background

- Joint research campaign between TU Wien, *RIEGL* & HafenCity University Hamburg
- Main objective:
  - evaluate the suitability of different remote sensing technologies for detailed habitat mapping
  - assess their ability to capture lakebed structure and aquatic vegetation
- Environment Lake Alm:
  - area: 0.85 km²
  - mean depth: 2.5 m
  - maximum depth: 9 m (spring funnel)

The lake provides ideal conditions for testing optical sensing techniques because of:
- clear water of 0.038 NTU (full optical penetration of the lake)
- visible spring funnels
- well-developed aquatic vegetation
  - Charophyceae and Elodea form a dense low-growing layer
  - Potamogeton grows up to 2 m above the bottom



Sensor Technology

ULi

- No. 3 from Fraunhofer IPM
- Active sensor using optical waves
- Green laser @ 532 nm (ToF)
- 44 ° Field-of-View
- Measurement range ~ 1.5 secchi
- Full waveform recording

[Fraunhofer IPM, 2026]

Bathymetric LiDAR

- VQ-840-GE & VUX-820-G from *RIEGL*
- Active sensor using optical waves
- Green laser @ 532 nm
- 40 ° Field-of-View (across)
- Measurement range ~ 1.8 secchi
- Full waveform recording

[Mena3D, 2026] & [*Riegl*, 2026]

Airborne Photogrammetry

- P1 camera from DJI
- Passive sensor
- min. picture interval of 0.7 s
- 35 mm focal length
- 45 MP

[Mediatec, 2026]

Sensor Technology – Additional Sensors

SideScanSonar

- 4125i from EdgeTech
- 600 kHz & 1600 kHz

[NauticExpo, 2026]

SingleBeam Echosounder

- Echorange from Airmar
- 200 kHz

[Airmar, 2026]

Sound Velocity Profiler

- AML-3 from AML Oceanographic
- Sound Velocity, Temperature, Pressure, Turbidity

[AML Oceanographic, 2026]

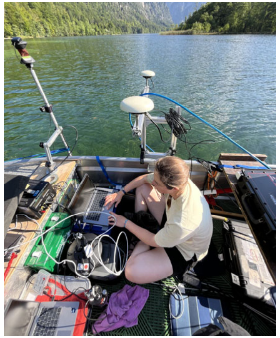
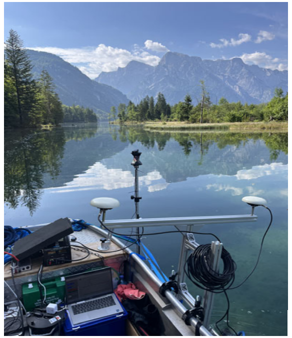
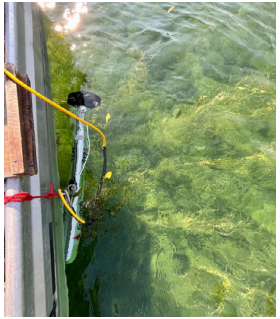
Underwater Camera

- Hero 12 Black from GoPro
- Collection of photo and video material

[GoPro, 2026]

Set-Up

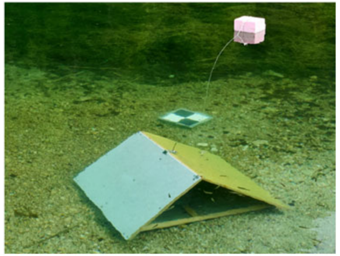
Survey Vessel


UASs


[Globe Flight, 2026]

Auxiliary Equipment




Acquired Datasets - Reference Dataset

- Reference data for evaluation of accuracy
  - Total station data
    - Above and below water (max. 3 m depth)
    - Unvegetated areas
  - Reference planes

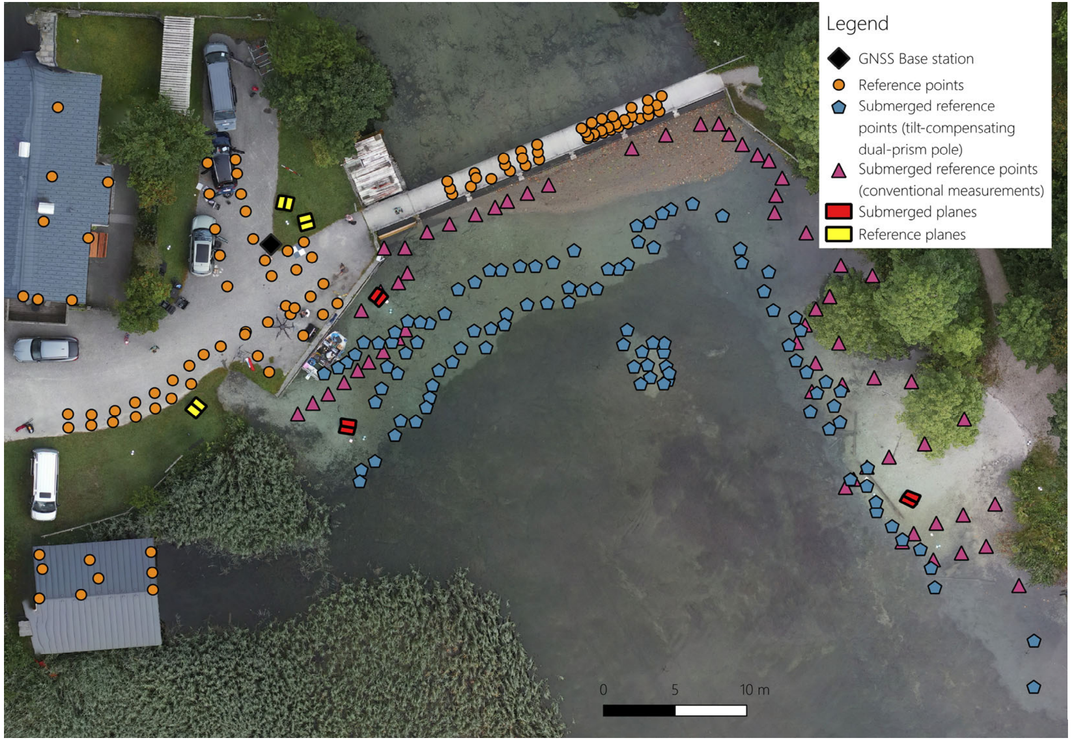
Workflow:
- Alignment using reference planes
- Evaluation against planar geometry
- Evaluation against total station points

—-> High initital offset due to geo-referencing

—-> Uncertainty above and below water is very similar

—-> Overall 2 - 3 cm deviation from reference

—-> Precision at reference planes is <= 1 cm



Acquired Datasets

ULi

- 2 days of survey
- line based continuous datasets with Palmer Scan Pattern
- data recorded in adjustment and 3B laser mode
- 100 kHz pulse repetition
- 1.5 mrad beam divergence
- 0.45 cm footprint at water depth of 3 m
- Full waveform recording
- Processing in Pulsalyzer / CloudCompare / Python

Bathymetric LiDAR

- 65 min flight time
- 4 starts
- 8 m/s flight speed
- 120 m above ground
- 100 kHz pulse repetition
- 1 mrad beam divergence
- 12 cm footprint at water surface
- 45 points/m²
- Full-waveform recording
- Processing in RiProcess / OPALS

Airborne Photogrammetry

- ~ 80 min flight time
- 5 starts
- 8 m/s flight speed
- 100 m above water surface
- 1.24 cm/pix
- 44.7 MP & 35 mm focal length
- 2231 images
- Processing in Metashape / OrientAL

Sensor Technology – Additional Sensors

SideScanSonar

- 2 days of survey
- line based continuous datasets
- 600 kHz & 1600 kHz acoustic frequency
- 180 HF images
- about 900 m survey lines covered
- Processing in Caris Hips & Sips

SingleBeam Echosounder

- 2 days of survey
- line based point-wise datasets
- 200 kHz acoustic frequency
- 1 Hz sampling rate
- Processing in QPS Qimera / QGIS

Sound Velocity Profiler

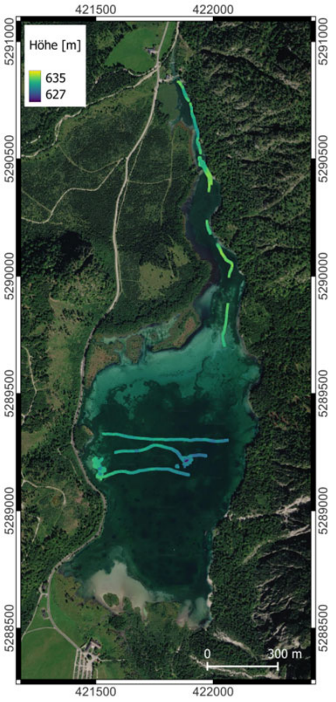
- 3 days of survey
- 13 profiles
  - 10 vertical profiles
  - 3 towing profiles at watersurface
- varying profile depth
- 5 profiles measuring SV and Turbidity
- 8 profiles measuring SV and CT
- Processing in Sailfish / Excel / QGIS

Underwater Camera

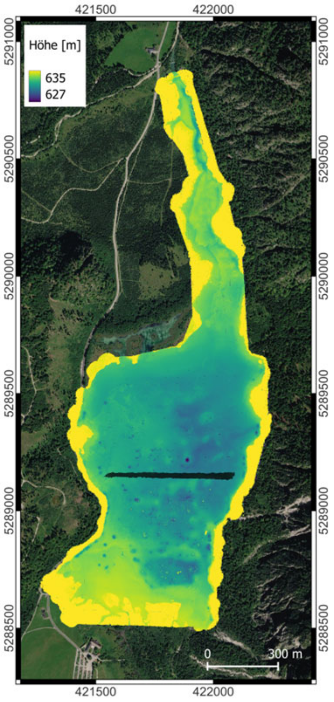
- individual images
- 17 videos
- Five videos geo-referenced with GNSS antenna on pole
- Scene reconstruction
- Qualitative comparison

Results - Overview Map

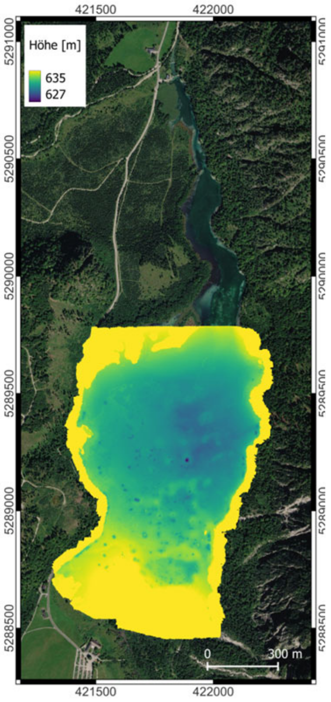
ULi



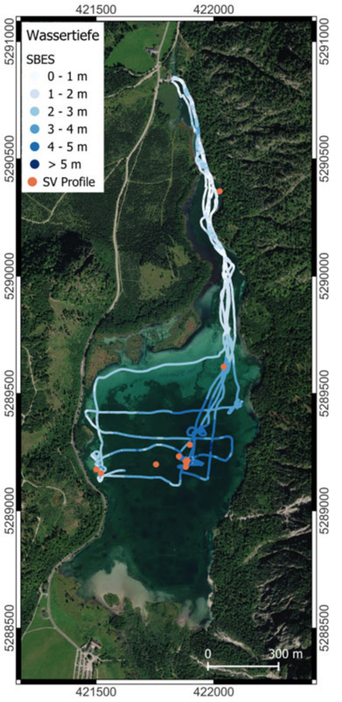
Bathymetric Lidar



Airborne Photogrammetry

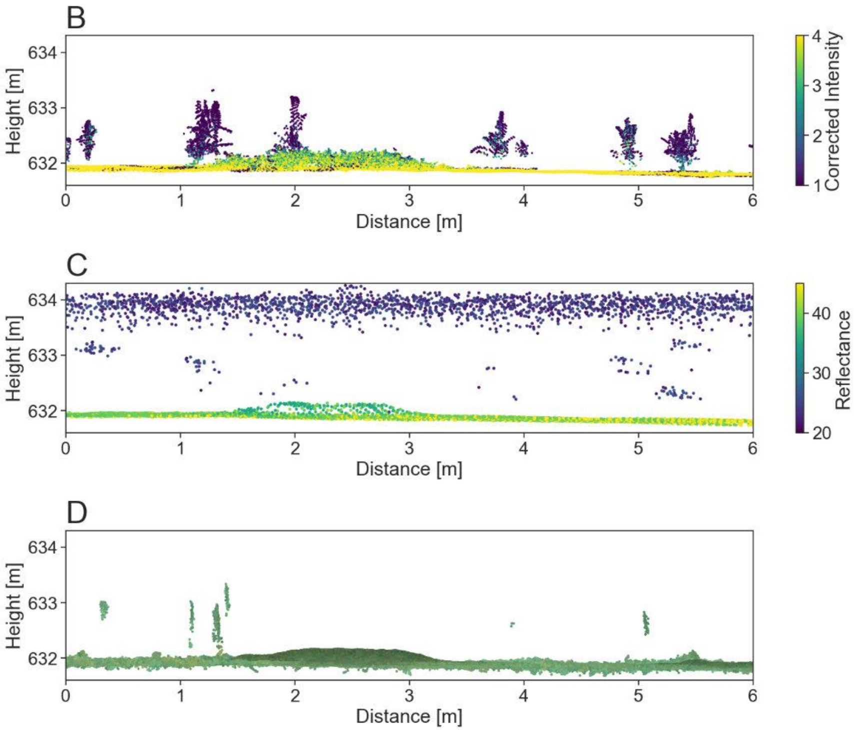


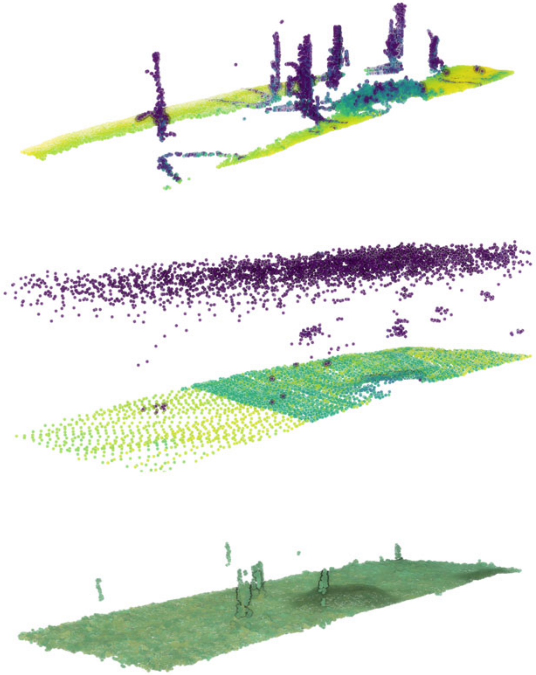
SBES



Results - Plants

ULi vs. Lidar vs. Photo

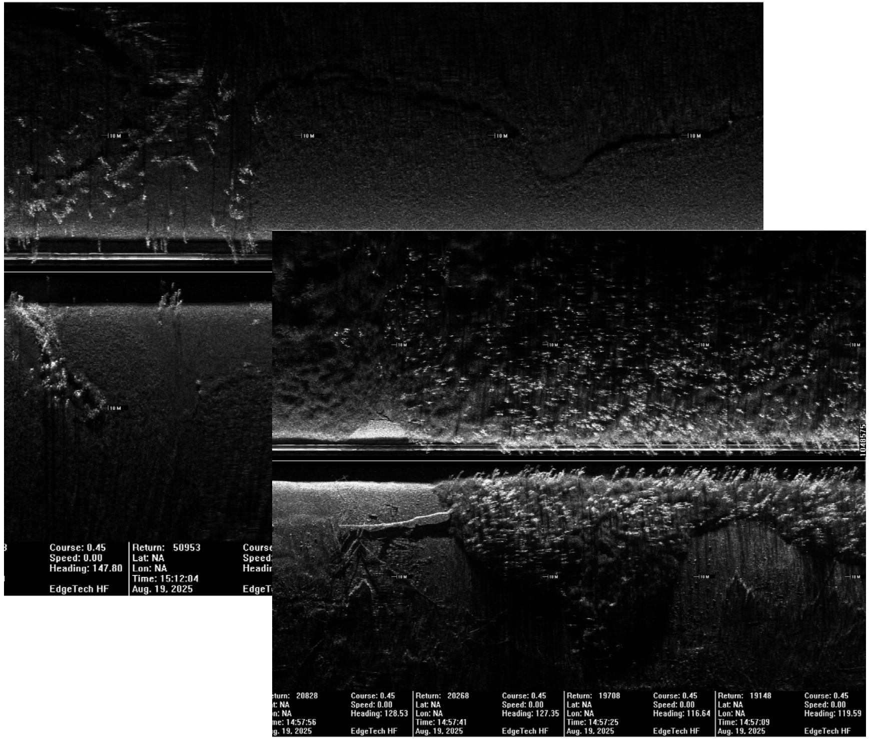


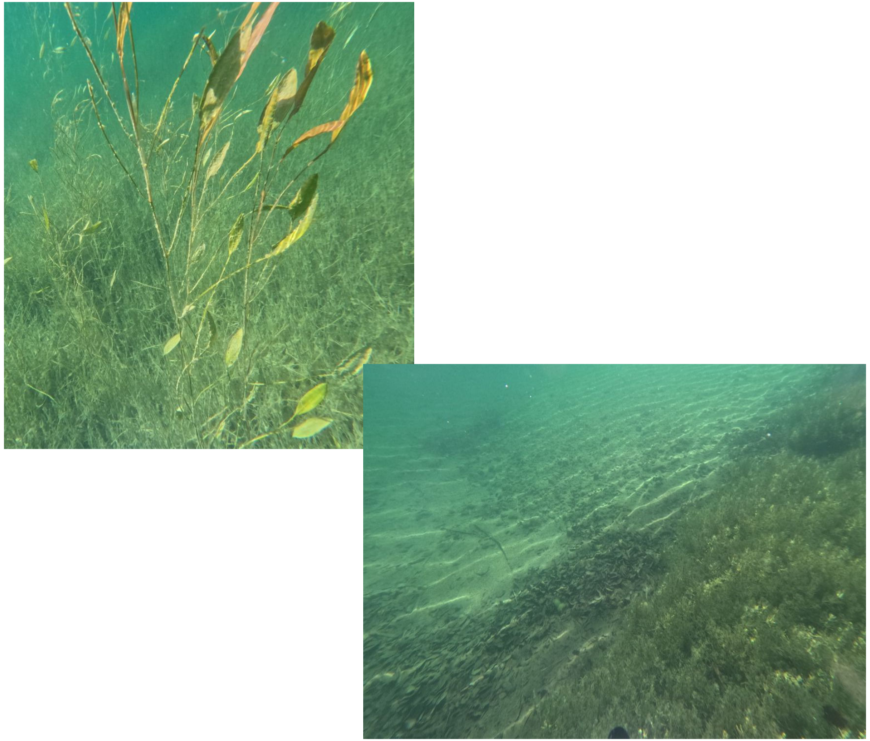


- ULi Underwater Laserscanner
- VUX-820 Airborne Bathymetric LiDAR
- DJI P1 camera

Results - Plants

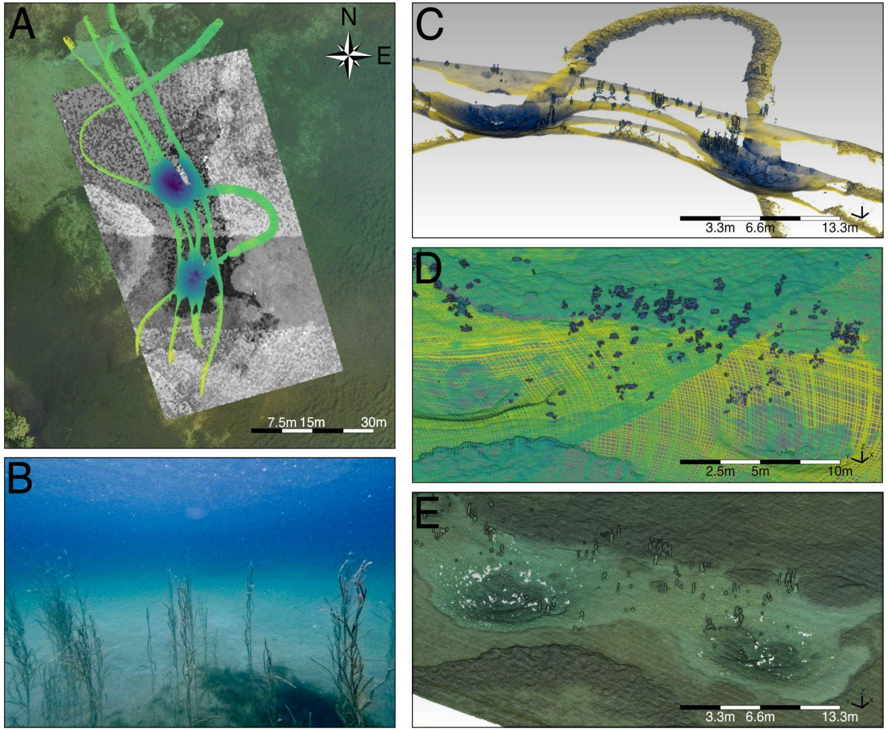
SideScanSonar vs. Camera





Results - Springfunnels

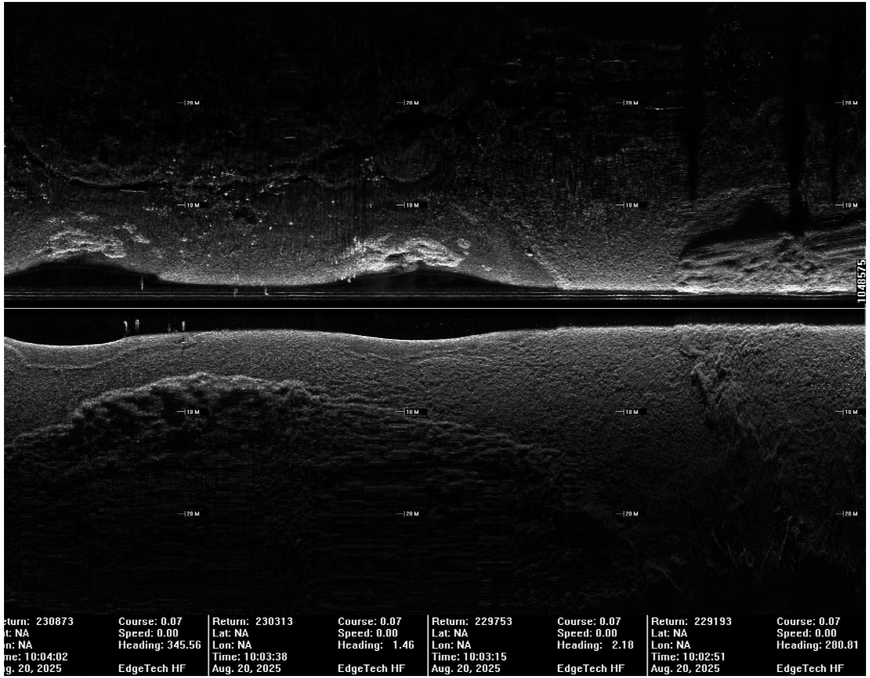
ULi vs. Lidar vs. Photo



- A = Combined Top-View Visualization of C, D & E
- B = GoPro
- C = ULi Underwater Laserscanner
- D = VUX-820 Airborne Bathymetric LiDAR
- E = DJI P1 camera

Results - Springfunnels

SideScanSonar vs. Camera

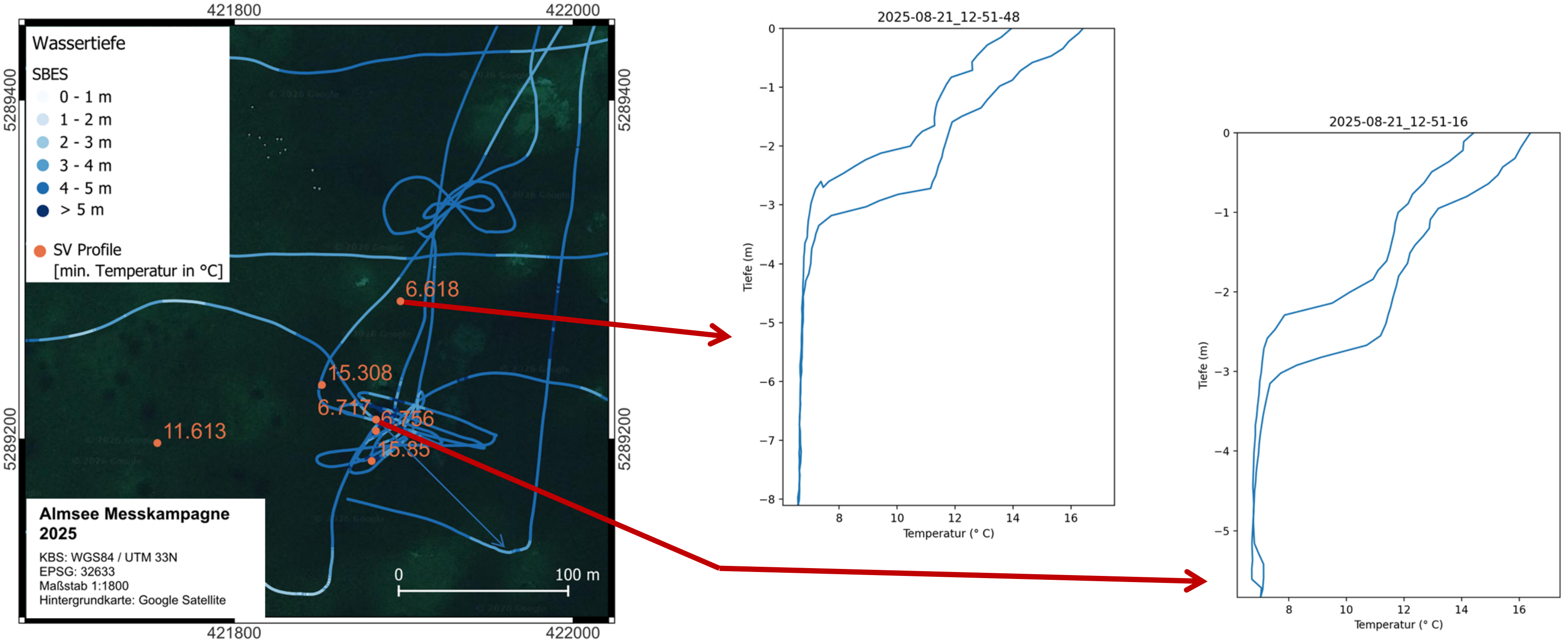


Challenges - Hardware & Processing

	ULi	LiDAR	Photogrammetry
Challenge	No ULi survey in motion before, no existing workflow to align a trajectory with ULi lidar data and georeference the resulting point cloud	Refraction correction usually not integrated but appended in workflows. Thus, strip adjustment usually does not consider refraction effects	Heterogeneous distortion of images due to refractive water surface
Solution	Mount IMU next to ULi, develop workflow to record and process trajectory seperatly and then merge with ULi data	Integrating refraction correction in strip adjustment	Modelling of refraction in bundle-block adjustment
Progress	SBG IMU mounted, workflow developed in Qinertia and Pulserlyzer, Solution developed to export georeferenced point cloud in UTM format	Two capable software solutions were realized at TU Wien	Prototypical solutions exist (e.g., in OrientAL (TU Wien) and at TU Dresden)

Challenge - variable Temperatures

Measured in vertical AML Profiles

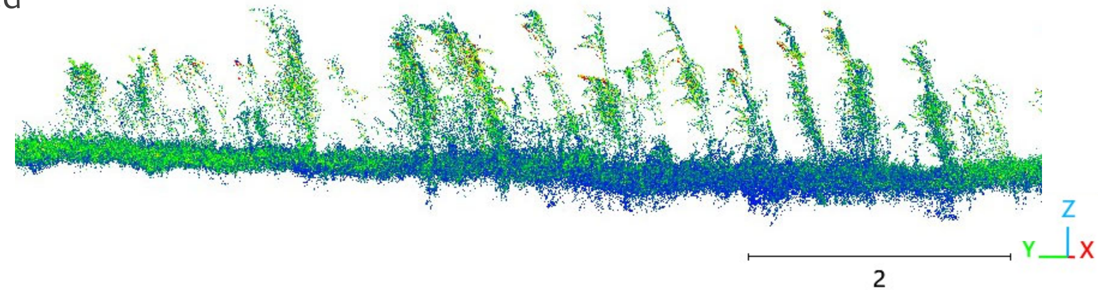


Comparison for Habitat Mapping

	ULi	LiDAR	Photogrammetry
Detail	Individual plants & leaves	Low and high grown vegetation clusters	Individual plants
Coverage	Sparse & strip wise	Complete coverage	Complete coverage but limited depth penetration
Efficiency	Detailed mapping, useful extension to airborne techniques	Suited for bathymetry and general vegetation detection	Suited for vegetation mapping, limited to vegetation canopy

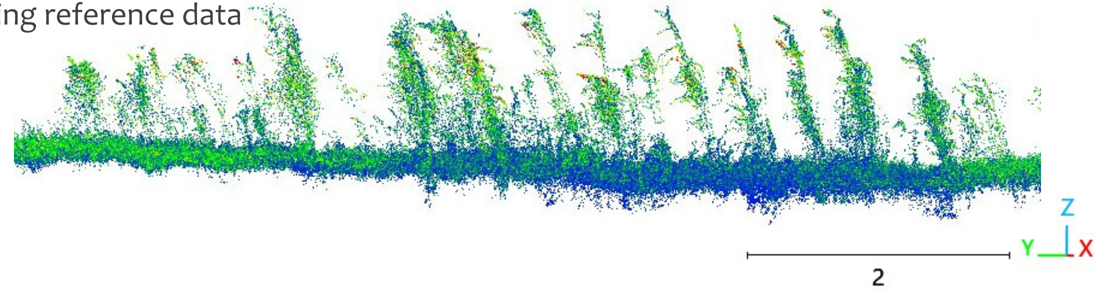
Conclusion

- Lake Alm is a suitable environment to compare optical sensing methods
- The clear water allows to focus on sensor technology and not ambient conditions
- Active lidar sensors provide full optical penetration, while camera misses only the deepest funnel in 9 m depth
- While airborne system cover the entire lake area, the shipborne systems are limited in coverage to the shiptracks
- ULi provides highest level of detail and resolution
- Different plant types can clearly be identified



Outlook

- An additional test site with more challenging conditions would be appropriate
- An additional MBES survey could be used as reference dataset
- Further to be investigated:
  - Penetration comparison of different sensors
  - ULi waveform analysis of plants
  - Vegetation (sub-)classification with airborne LiDAR
  - Accuracy analysis of LiDAR and photo data using reference data



References

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Thank you very much!

Hydrographentag 2026

TU WIEN GEO
RIEGL LASER MEASUREMENT SYSTEMS
Lucas Dammert – Annika L. Walter – Ellen Heffner
hcu HafenCity Universität Hamburg