VIENNA UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF GEODESY AND GEOINFORMATION
RESEARCH GROUPS PHOTOGRAMMETRY & REMOTE SENSING

HYDRO 2024
Hydrographic Conference

# Optical hydrography - the DGPF's contribution to mapping and monitoring inland and coastal waters

with contributions by: Ramona Baran, Katja Richter, Laure-Anne Gueguen, Jan Rhomberg-Kauert, David Mader, Christian Mulsow, Hannes Sardemann, and Robin Rofallski

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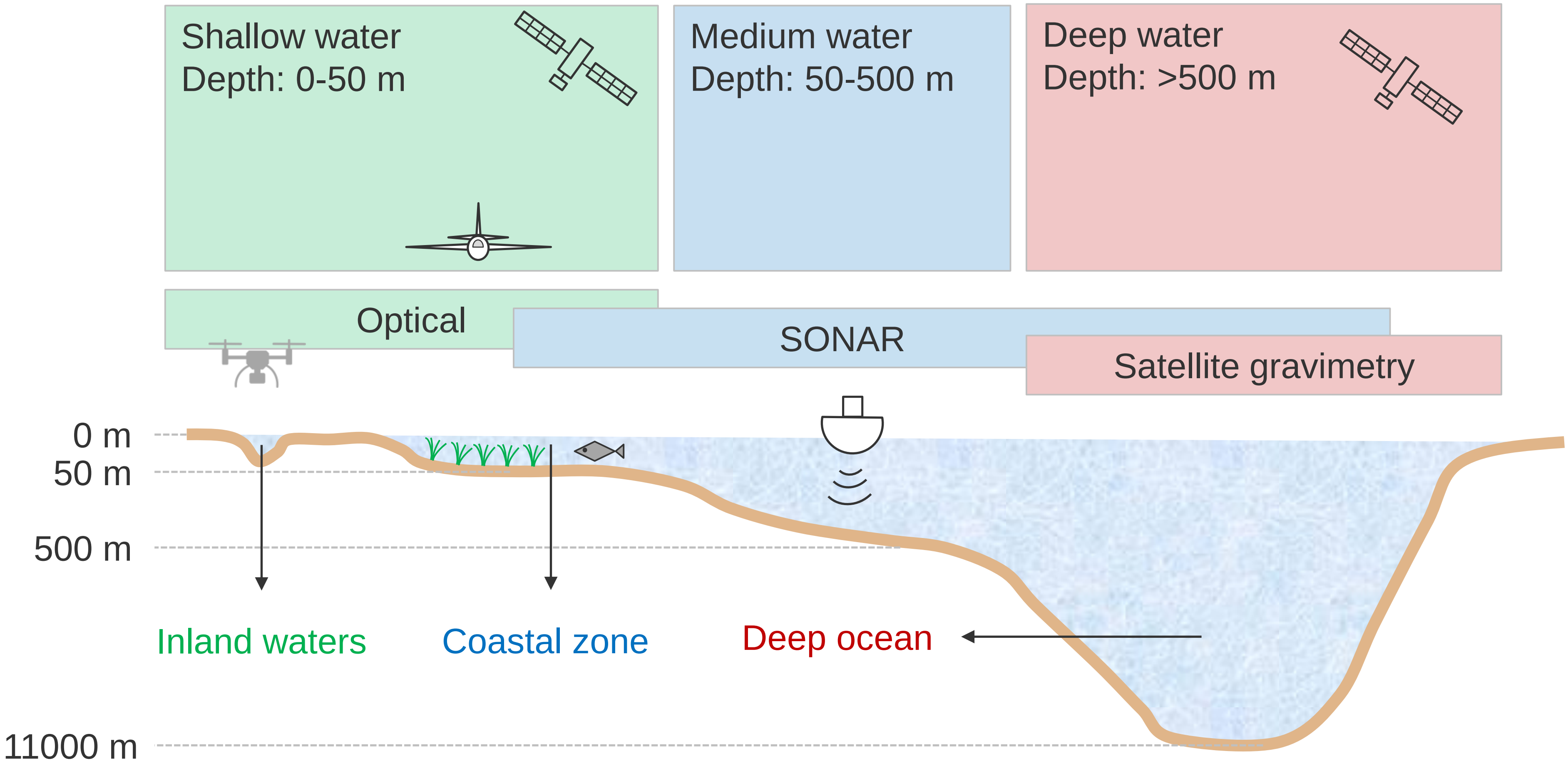
TU Wien, Department of Geodesy and Geoinformation
Research Group Photogrammetry (E120.7)

Deutsche Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V.
German Society for Photogrammetry, Remote Sensing and Geoinformation

# About DGPF...

- Goals of DGPF...
  - R&D in phogrammetry, remote sensing and geo-information
  - Promotion of scientific exchange
  - Dissemination of scientific research and outreach (science, society and technology)
- Research
  - Working groups: Sensors & Platforms, Photogrammetry, RS, Geo-Info, Dissemination
  - Hydrography related:
    - RADAR and **LiDAR**: **Gottfried Mandlburger**
    - Application Geology and **Hydrography**: **Katja Richter (since 2024),** G. Mandlburger (till 2024)
- Exchange/Dissemination/Outreach
  - Annual conferences (every 3rd year together with AT and CH)
  - Workshops: e.g. Unmanned Systems Conference @ Intergeo 2024
  - PFG – Journal of Photogrammetry, Remote Sensing and Geoinformation Science
    - SI: Bathymetry from Images, LiDAR and Sonar (2021)
    - SI: Recent Developments in Multi-Media and Underwater Photogrammetry (2022)
    - SI: Assessment of Coastal Vulnerability to Sea Level Rise Using Remote Sensing (2024)

# Optical Methods - SONAR - Gravimetry

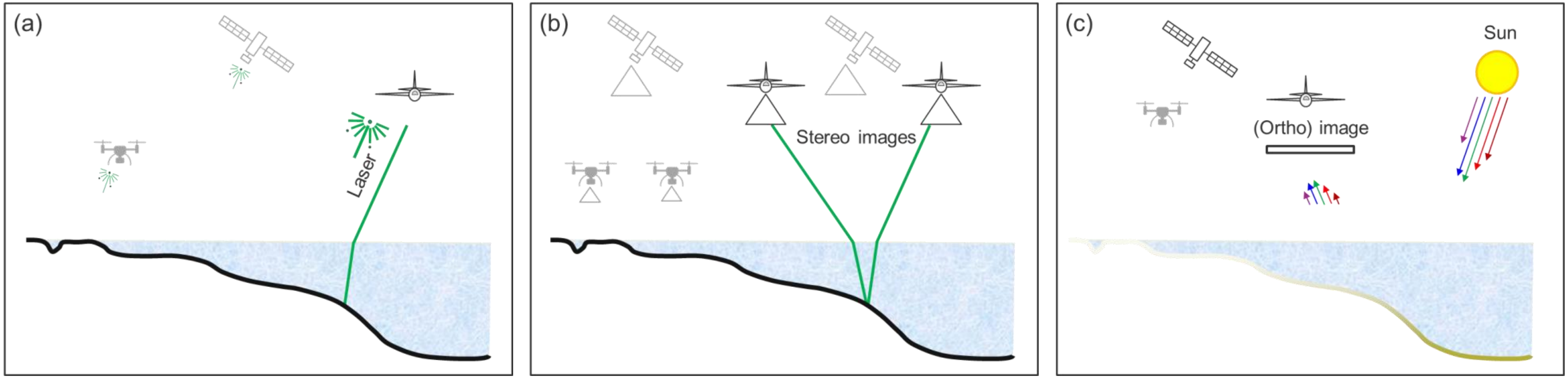


# Optical hydrographic methods

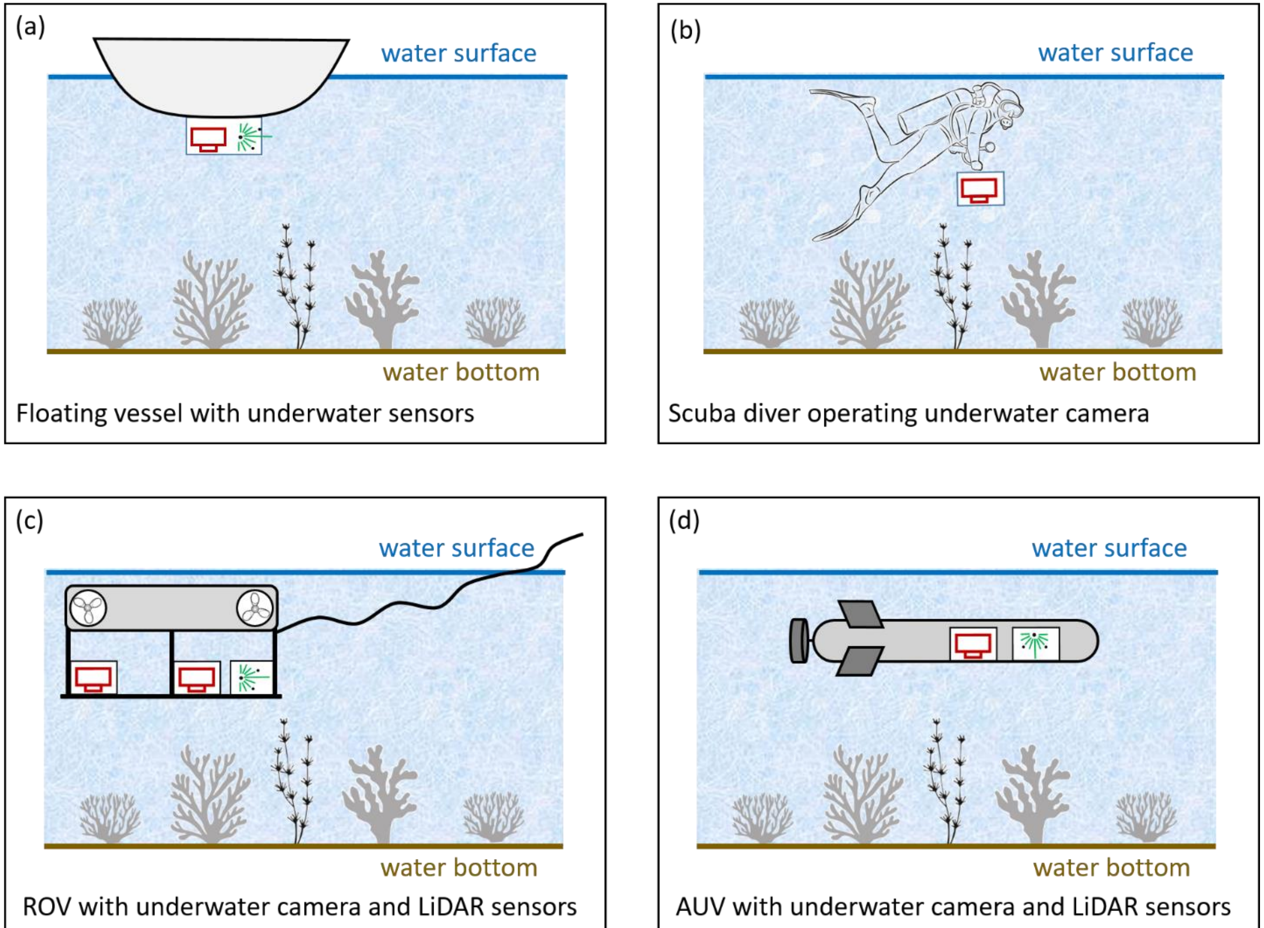
**Laser bathymetry**

**Multimedia photogrammetry**

**Spectrally derived bathymetry**



# Underwater sensor configurations



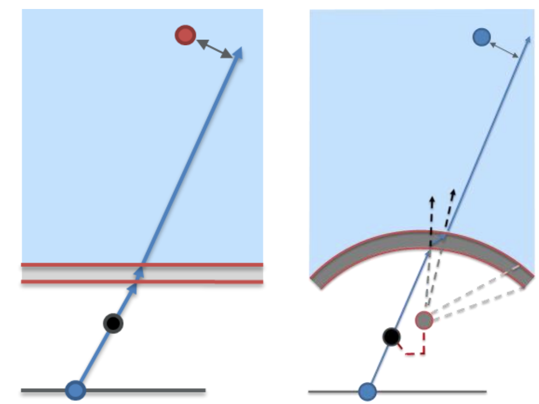
# Efficient Ray Tracing for Multimedia Photogrammetry

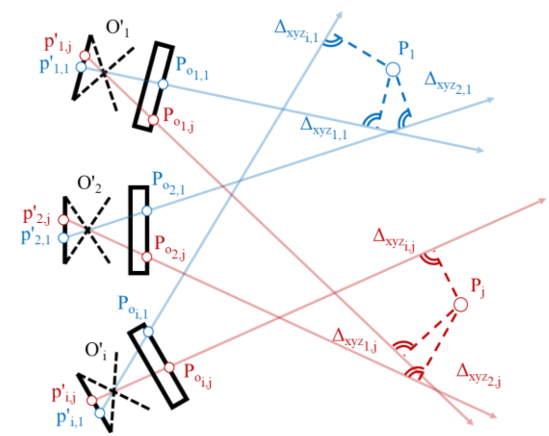
**Problem**

- Refraction at interfaces must be compensated, e.g. “ray tracing”
  - Strict approach
  - Slow, iterative approach – non-analytical

**Novel Approach**

- Shift optimization from image space to object space
  - Analytical derivatives for speed improvement
  - Reducing computational effort by 10x
  - Strict approach
- Bundle adjustment allows optimizing additional parameters
  - Interface orientation, refractive indices
- Transfer to other interfaces, e.g. decentered dome ports
  - Optimize offset between: perspective center <-> dome center





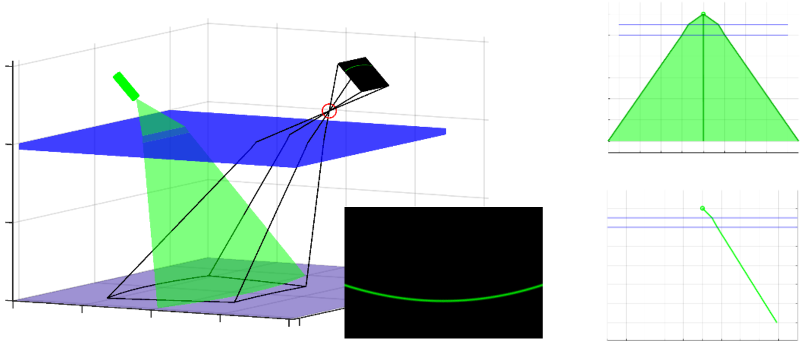

**Rofallski**, R. & Luhmann, T. (2022): *An Efficient Solution to Ray Tracing Problems in Multimedia Photogrammetry for Flat Refractive Interfaces.* PFG I/2022

**Rofallski**, R.; Menna, F.; Nocerino, E.; Luhmann, T. (2022a): *An Efficient Solution to Ray Tracing Problems for Hemispherical Refractive interfaces*. ISPRS Annals of Photogram., Remote Sens. and Spatial Inf. Sciences (V-2-2022)

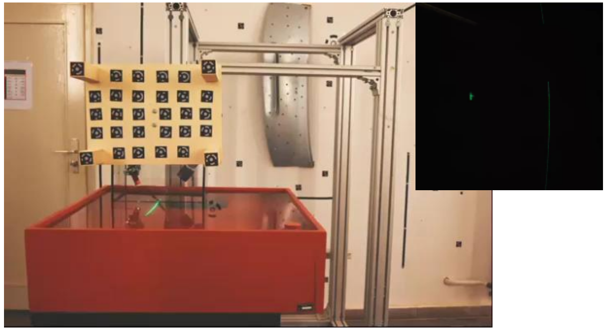
# Accuracy Analysis of an Oblique Underwater Laser Lightsheet Triangulation System
## Sardemann, Mulsow, Maas (TU Dresden), 2021, PFG

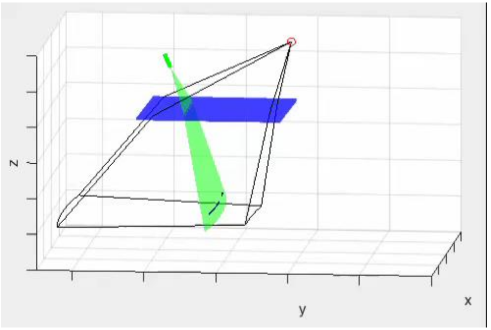
### Mapping shallow waters with a remotely operated surface vessel

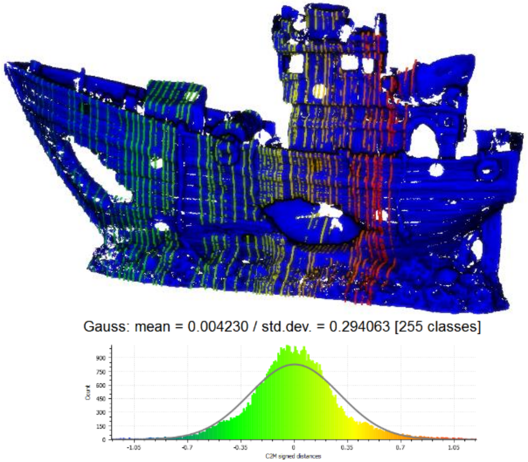
### Deformation of laser plane at media boundaries



### Accuracy analysis in lab experiment






TECHNISCHE UNIVERSITÄT DRESDEN

# Compensation of wave effects in Photobathymetry

Christian Mulsow, Optical Hydrography II
Thursday, 12:00, Auditorium A

**Problems when imaging through water surfaces:**

- glint effects (due to specular reflection)
- image distortion (due to refraction)

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-2-2024
ISPRS TC II Mid-term Symposium "The Role of Photogrammetry for a Sustainable World", 11–14 June 2024, Las Vegas, Nevada, USA

**Concepts for compensation of wave effects when measuring through water surfaces in photogrammetric applications**

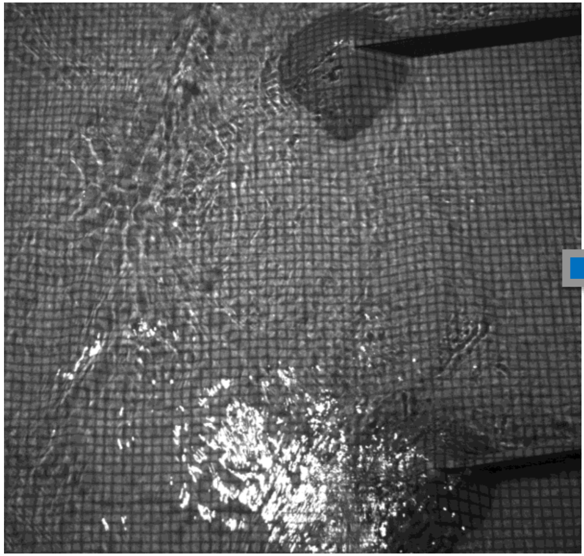
Christian Mulsow [1], Hannes Sardemann [1], Laure-Anne Gueguen [2], Gottfried Mandelburger [2], Hans-Gerd Maas [1]

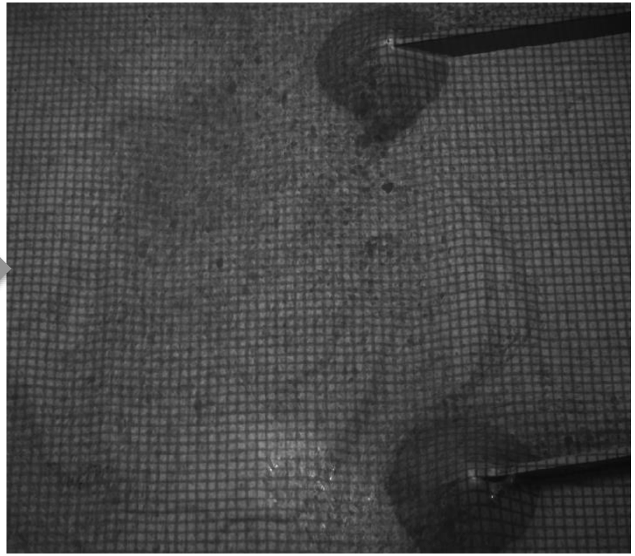
**Solution:**

- Taking image sequences rather than single images
- Analysis of changes in image- and/or object space

**Result**:

- corrected image corresponding to an image taken through flat water surface
- corrected underwater DEM

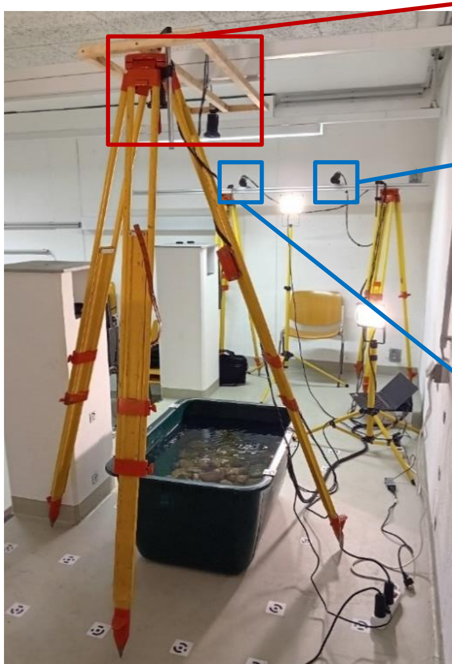


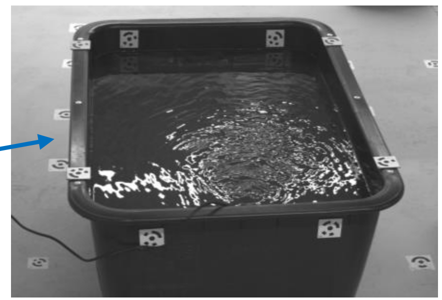


# Lab experiment: Simultaneous surface and bottom

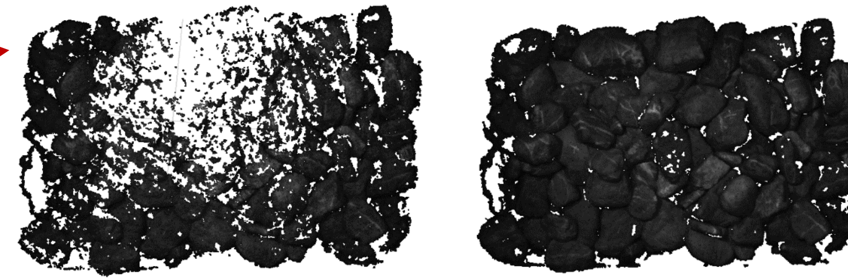
- multi-camera setup simultaneously triggered by an Arduino
- 2 oblique and 2 nadir looking cameras
- water tank filled with 2 layers of stone

Laure-Anne Gueguen: Opt, Hydrogr. II
Thursday, 11:35, Auditorium A

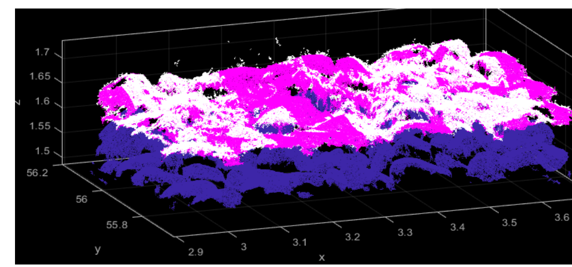


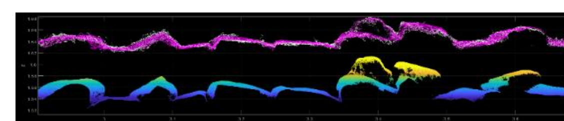


Oblique stereo pair



Dense point cloud of topography from nadir images with dynamic surface (left) and flat surface (right)

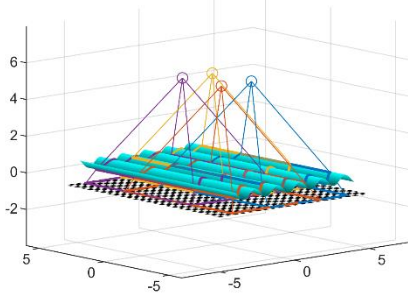


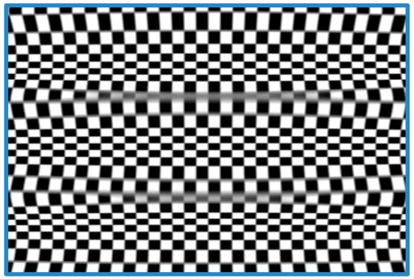



Observation of the effect of refraction from the water surface on the topography reconstruction (purple is ground truth)

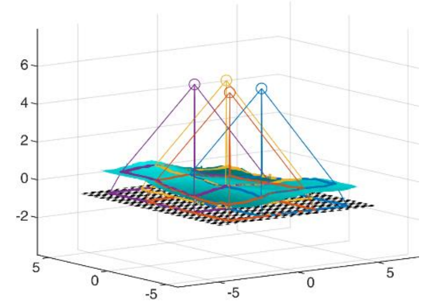
# Multimedia Photogrammetry with non-planar Water Surfaces – Accuracy Analysis on Simulation Basis
Sardemann, Mulsow, Guegen, Mandlburger, Maas, 2024, ISPRS Archives

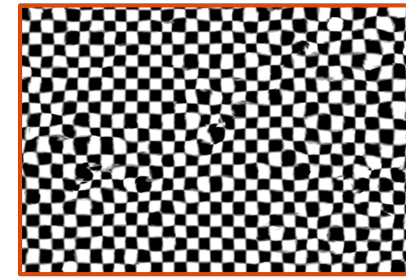
## Sinusoidal water surface



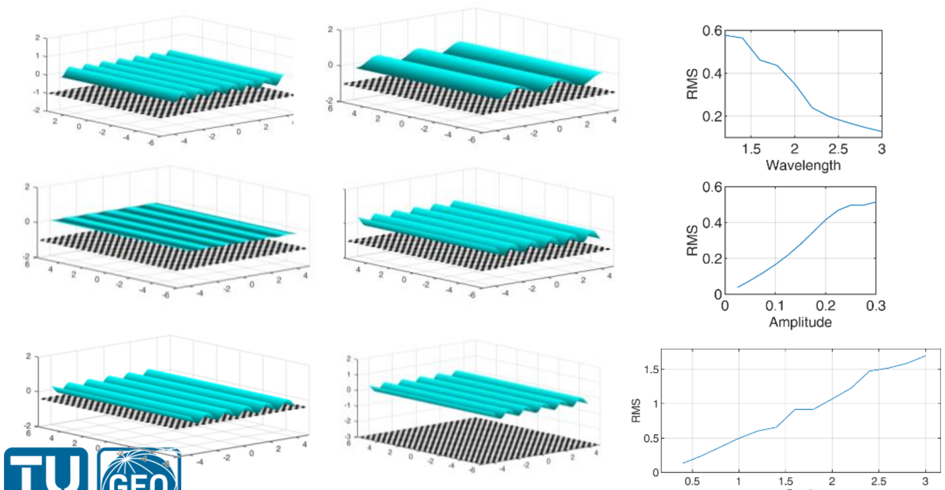


## Freeform water surface

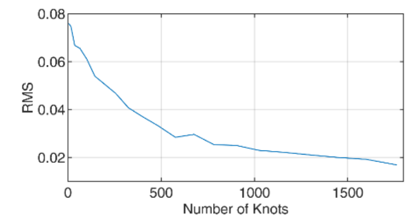




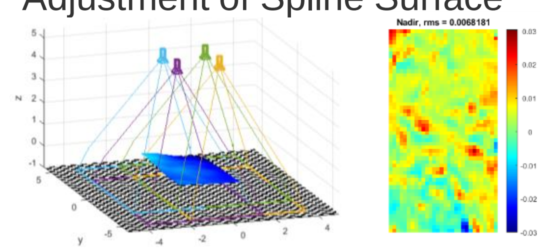
## Influence of water surface on bathymetry



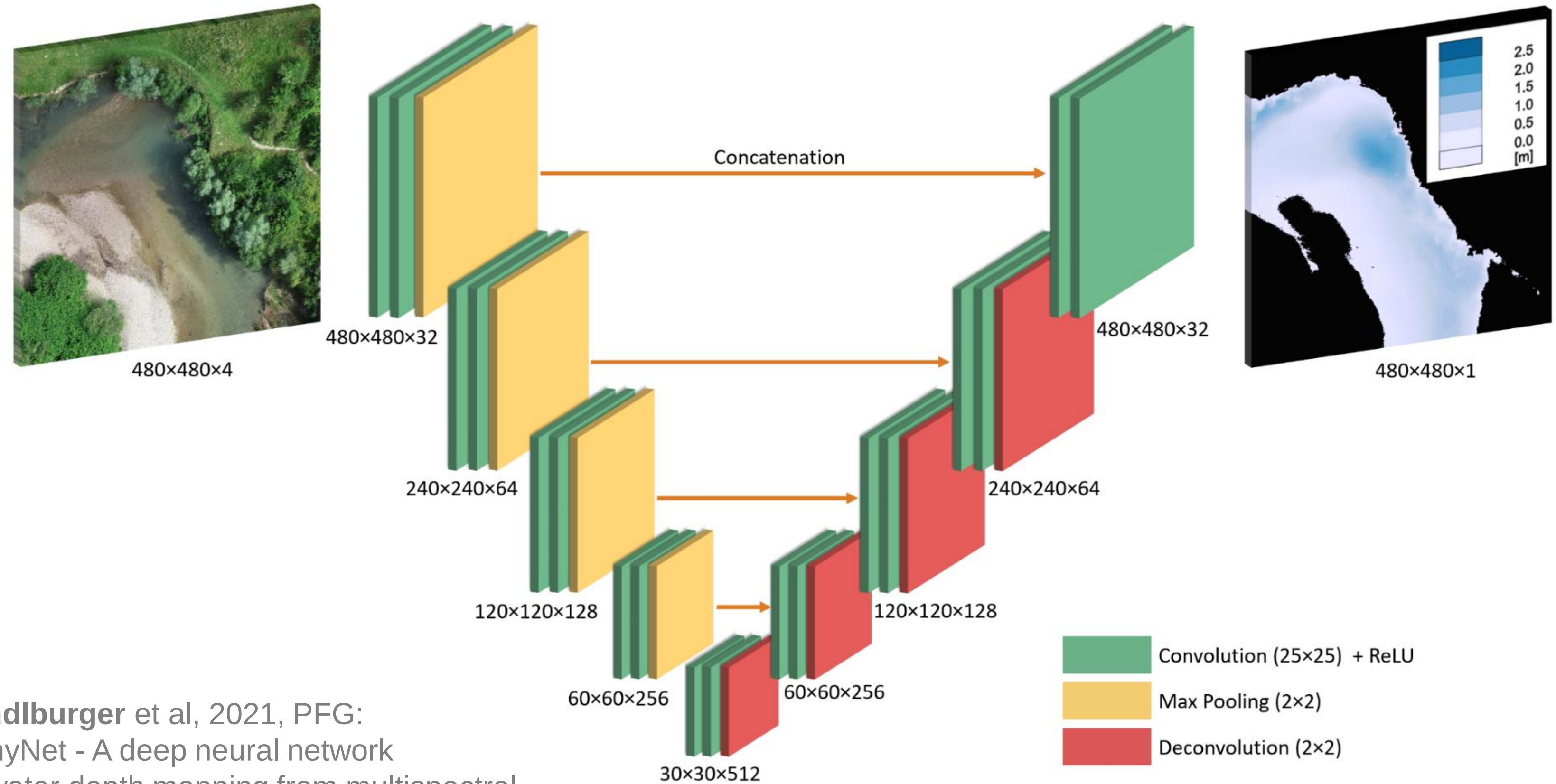

## Influence of resolution of water surface




## Adjustment of Spline Surface



# BathyNet: U-Net CNN



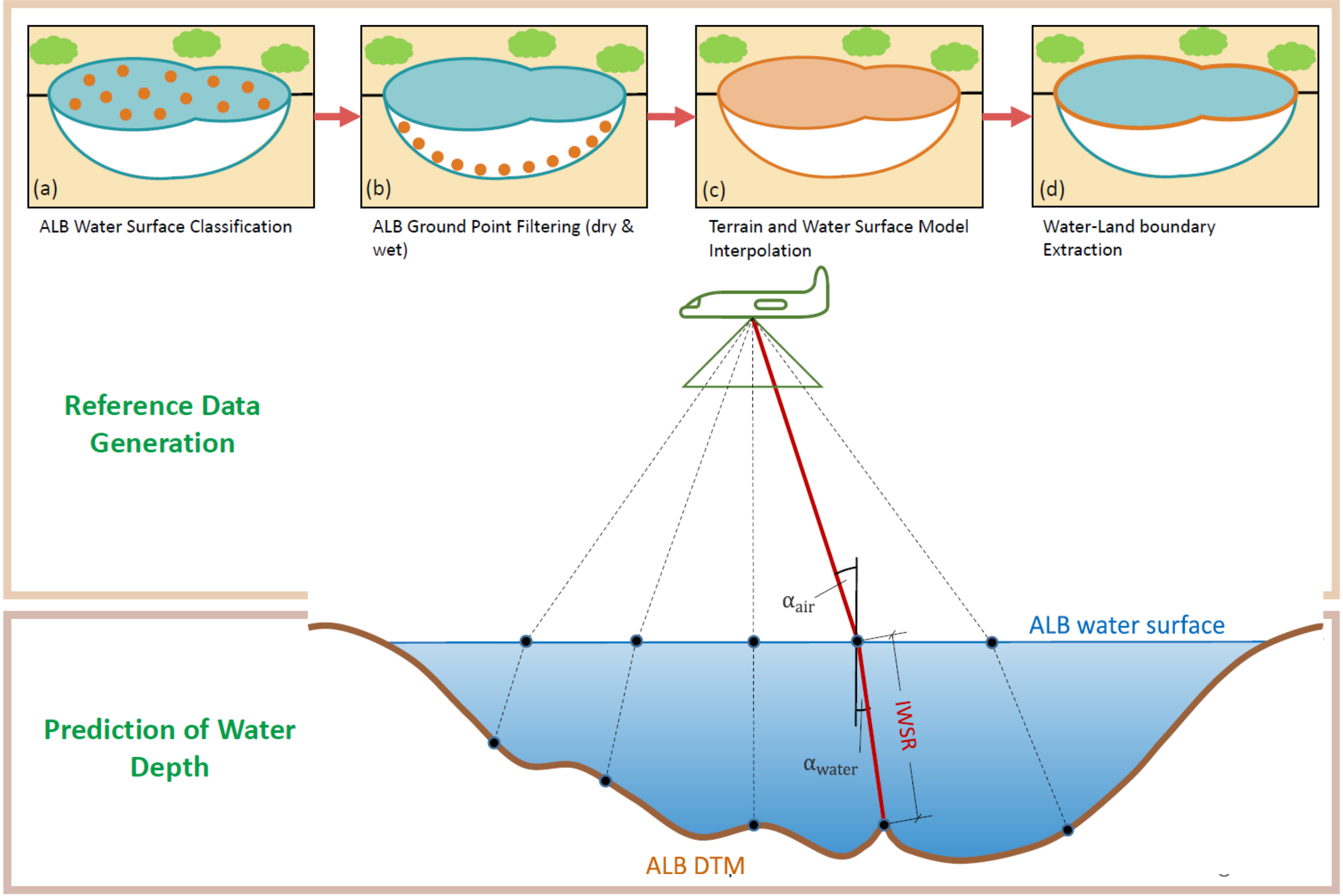

**Mandlburger** et al, 2021, PFG:
BathyNet - A deep neural network
for water depth mapping from multispectral
aerial images. Journal of Photogrammetry and Remote Sensing

# BathyNet: Combining photogrammetry and DL

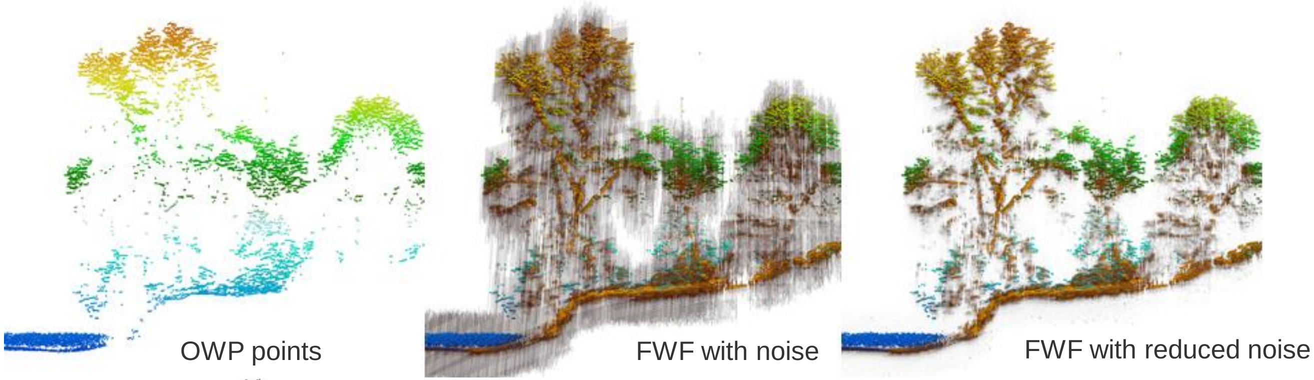
Concurrent **Lidar** as **reference data** (DTM, DWSM)

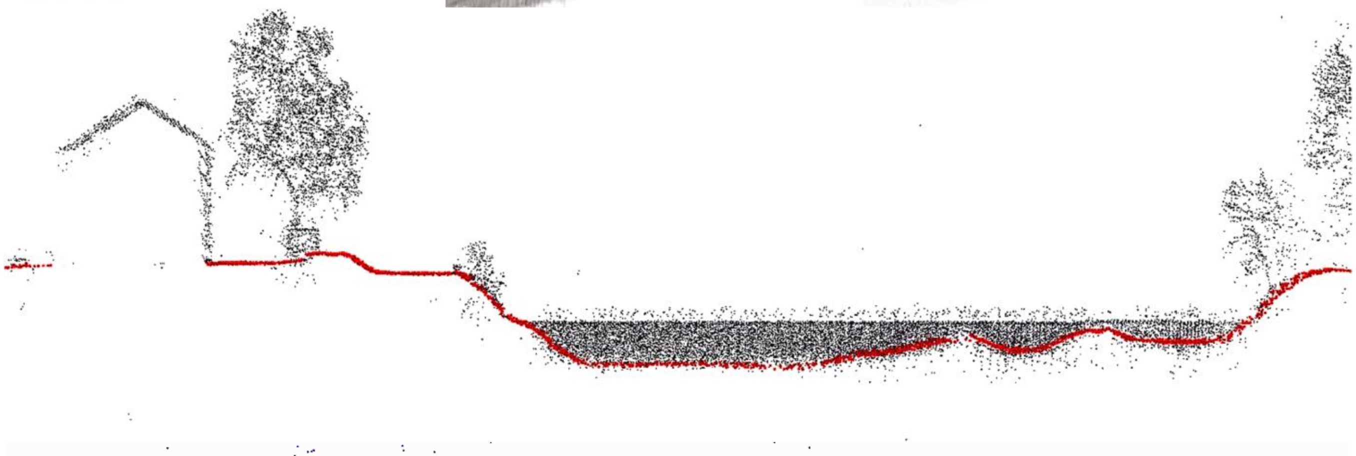
**Photogrammetric pipeline** image ori and ray tracing)

**CNN-based DL** and post processing (median filtering)



# Integrated Full-Waveform Analysis and Classification Approaches for Topo-Bathymetric Data Processing and Visualization in HydroVISH (*Steinbacher et al. 2021)*



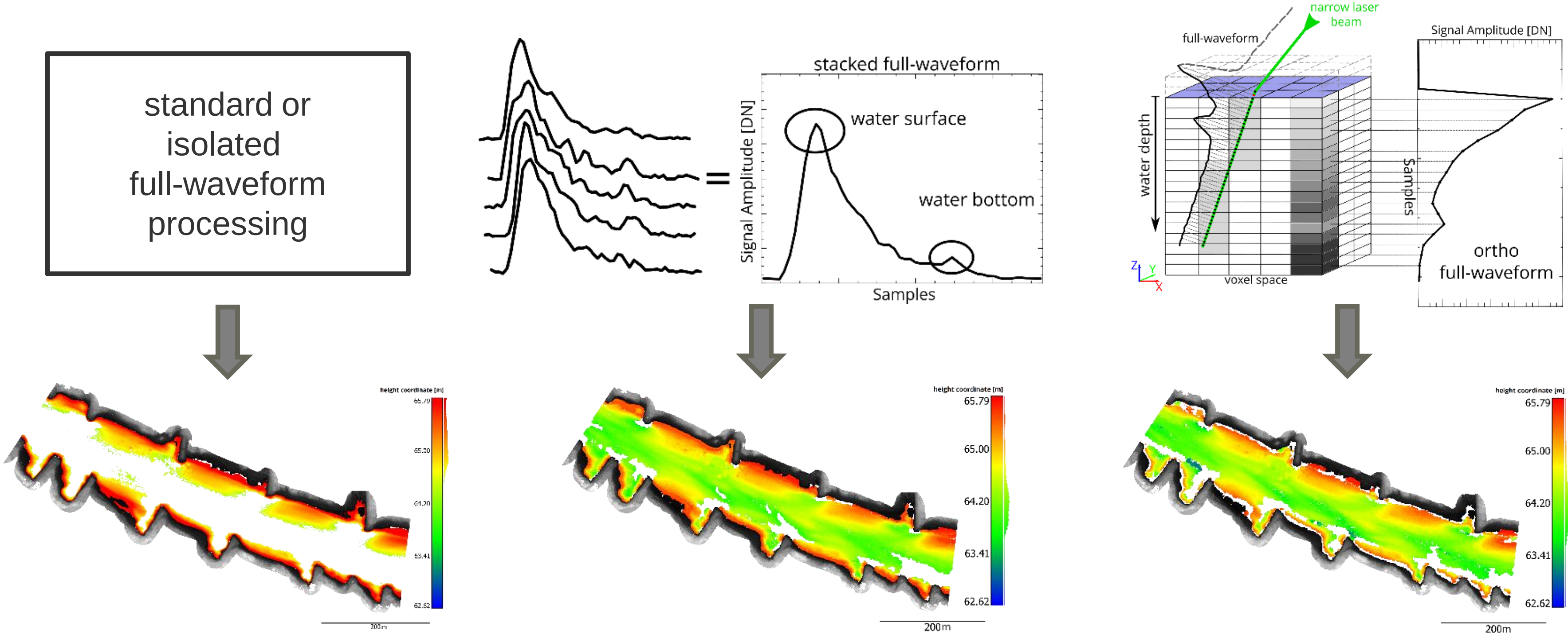
http://ahm.fiberbundle.net/HydroVish/

- **FWF tools** for better water ground coverage & improved penetration depth
- **Preclassification of waterbody** using e-function fitting of FWF
- **Point classification toolset** in HydroVISH

Ramona Baran,
Optical Hydrography II
Thursday, 10:45,
Auditorium A

Steinbacher, **Baran** et al., 2021, PFG: Integrated Full-Waveform Analysis and Classification Approaches for Topo-Bathymetric Data Processing and Visualization in HydroVISH

# Full-Waveform Stacking Techniques



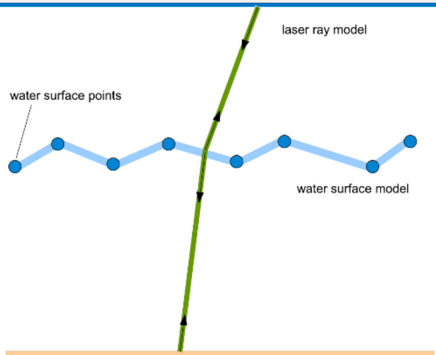

| | OWP | sigFWFS | volFWFS |
|---|---|---|---|
| bottom coverage | 100% | 204 % | 213 % |
| water depth | 1.65 m | 2.10 m | 2.15 m |

D. **Mader**, K. Richter, P. Westfeld, H.-G.Maas:

**sigFWFS:** Potential of a Non-linear Full-Waveform Stacking Technique in Airborne LiDAR Bathymetry (PFG Journal)

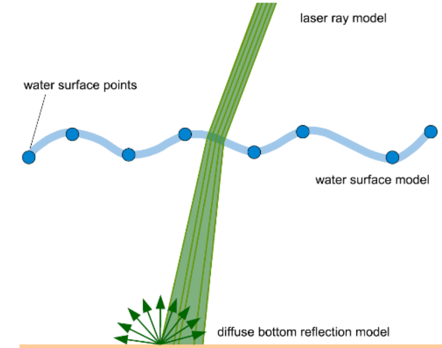
**volFWFS:** Volumetric nonlinear ortho full-waveform stacking in airborne LiDAR bathymetry for reliable water bottom point detection in shallow waters (ISPRS Journal)

# Geometric Modeling of Laser Pulse Propagation in ALB

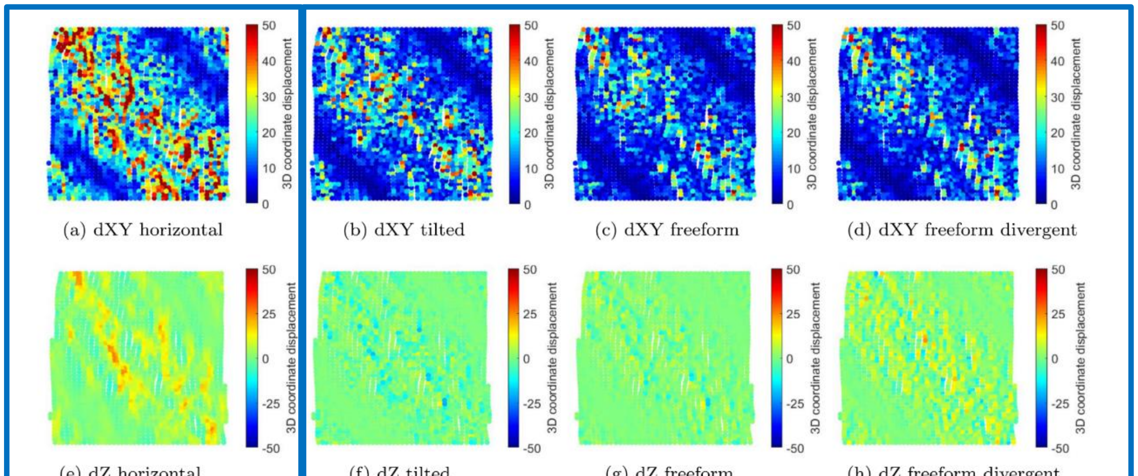



conventional model

Improvement of
water surface model & laser ray model




enhanced model




**Richter** et al., 2021, PFG: Refined Geometric Modeling of Laser Pulse Propagation in Airborne LiDAR Bathymetry

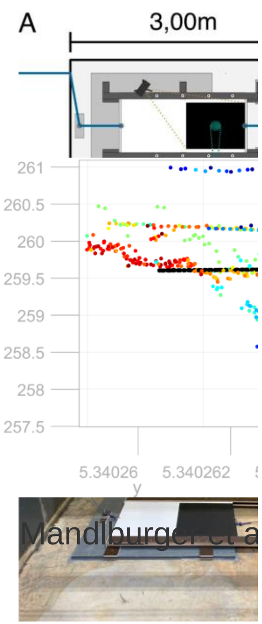
Katja Richter,
Water column analysis
Wednesday, 16:40,
Auditorium B

Results laser bathymetry simulator: Absolute coordinate displacements at the water bottom

TU WIEN GEO TECHNISCHE UNIVERSITÄT DRESDEN

# Turbidity dependent depth bias in UAV-bathy LiDAR

- Observation in practice: Overestimation of depth with small footprint LiDAR → Hypothesis: multi-path effects

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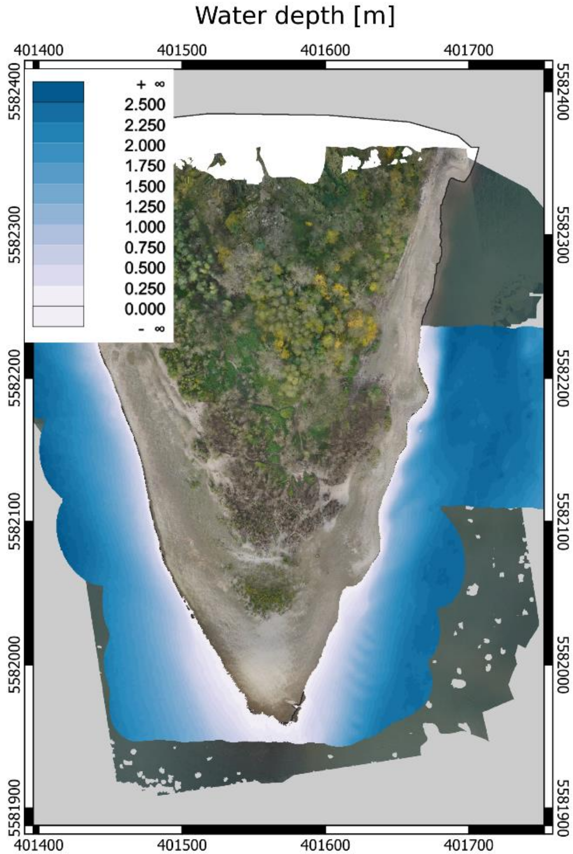
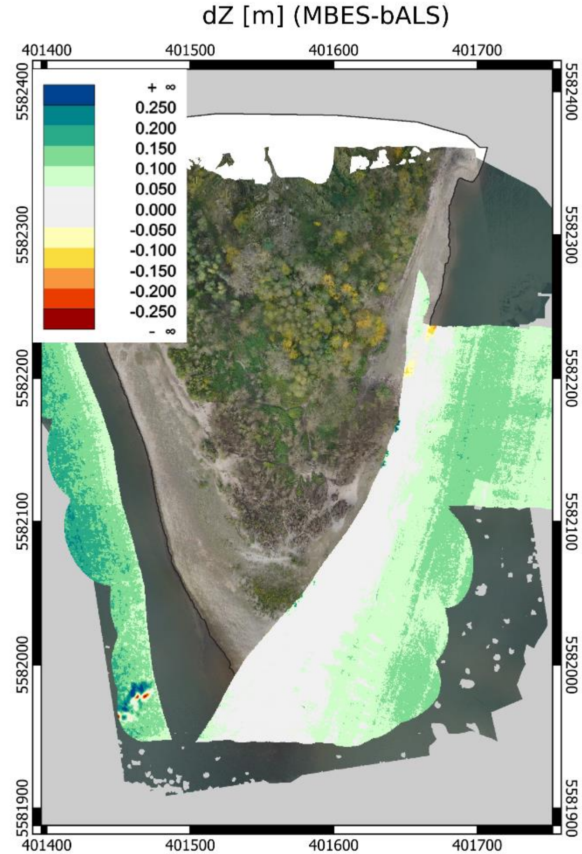
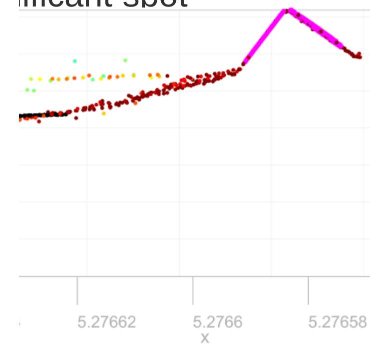



ificant spot




AR Sensor

y bias with SVB

mendation: NTU and measurements.

Data: BfG/Koblenz

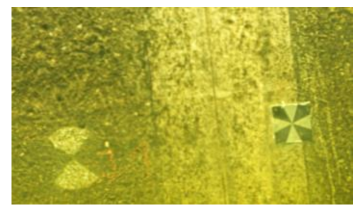
# Monitoring of hydroelectric power dam – Pack/Styria

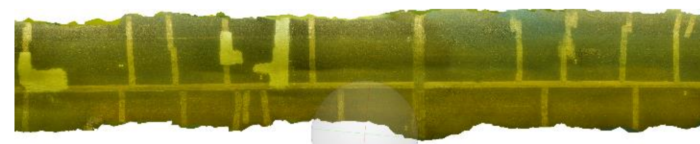
- **Use of the emptying 03/2023**

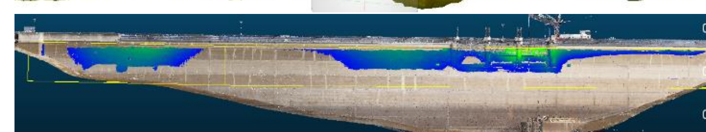
- Markings applied and measured with high precision using a total station
- Water side recorded with terrestrial laser scanner
- Reference model for comparisons / further development of underwater photogrammetry

**Results of underwater photogrammetry**

- Around 1000m$^2$ area based on ROV images
- High resolution (details recognizable)
- Difference to the reference model calculated
- Navigation to detailed photos located on the dam

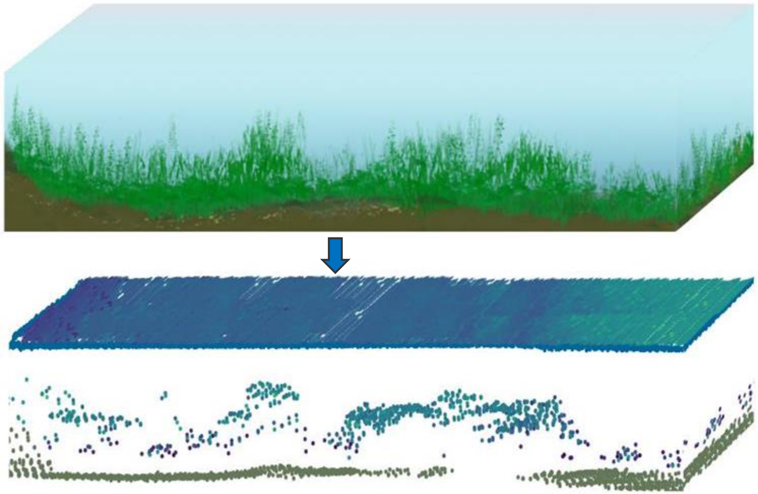


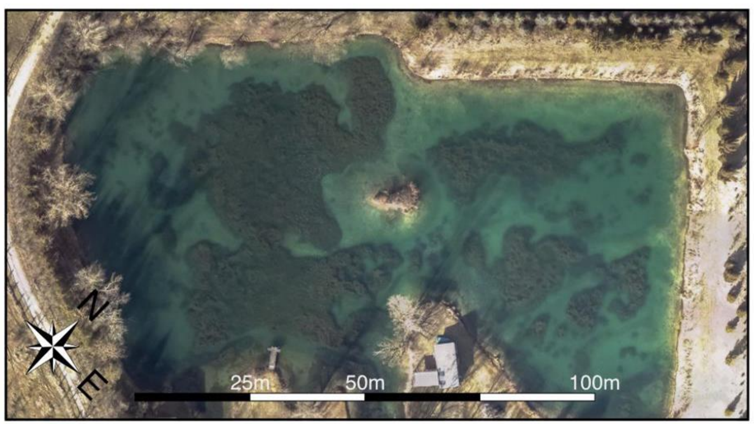


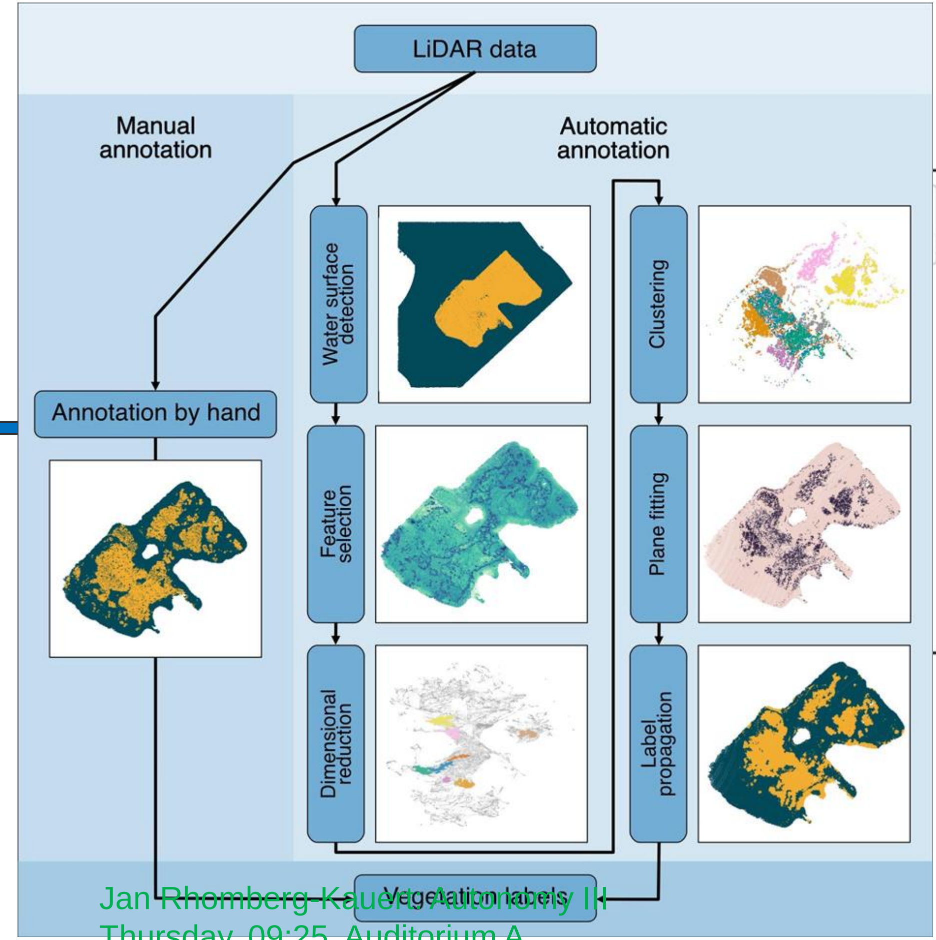


**Grömer** et. al., 2024: High-detail and low-cost underwater inspection of large-scale hydropower dams, ISPRS Archives

# Underwater vegetation monitoring through bathymetric LiDAR






Jan Rhomberg-Kauert: Autonomy III
Thursday, 09:25, Auditorium A

# Summary

- DGPF's contribution to optical hydrography
  - Tackling challenges in
    - Laser bathymetry - Multmedia photogrammetry - Sectrally derived bathymetry
  - Aquisition-related
    - Through-water and underwater
  - Sensor-related
    - UAV-bourne sensors
    - New underwater system (laser lightsheet triangulation)
    - Synchronized camera systems
  - Methods-related
    - Laser waveform processing and understanding
    - Water surface dynamics
    - Software solutions
  - Application-related
    - Monitoring of hydro-power dams → sustainable energy production
    - Submerged vegetation → proxy for climate change
    - Turbidity → environmental state

# Save the data

- ISPRS WG II/7 Workshop on Underwater Photogrammetry
- Jointly organised by **ISPRS** and **DGPF**
- **Venue: TU Wien**
- **Date: July, 08-11, 2025**
- **Program**
  - Invited lectures
  - Call for papers (in preparation)
  - Tutorials
  - Demonstrations (Water lab TU Wien)
  - Excursion (pre Alpine Pielach River)
  - Social events (Ice breaker, conference dinner)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# Optical hydrography - the DGPF's contribution to mapping and monitoring inland and coastal waters

with contributions by: Ramona Baran, Katja Richter, Laure-Anne Gueguen, Jan Rhomberg-Kauert, David Mader, Christian Mulsow, Hannes Sardemann, Robin Rofallski

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TU Wien, Department of Geodesy and Geoinformation
Research Group Photogrammetry (E120.7)

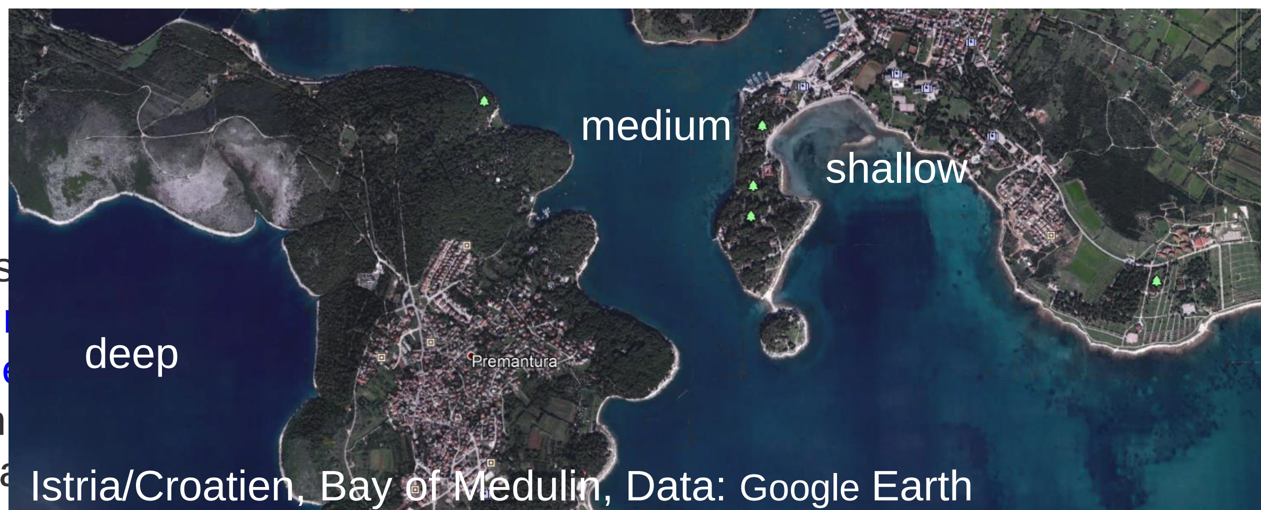
Deutsche Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V.
German Society for Photogrammetry, Remote Sensing and Geoinformation

# Basic color-to-depth relation

e.g. Lyzenga et al, 2006: Multispectral Bathymetry Using a Simple Physically Based Algorithm

$$L(h) = L_S + L_B e^{-\propto h}$$

$L(h)$ ......... upwelling radiance depending on the water depth *h*
$L_S$ ............. **surface** reflections and **volume scattering** from **infinitely deep** water
$L_B$ ............ transmission **losses** through **surface** + **bottom reflectance** + **volume scattering**
$\propto$ ............. sum **of diffuse attenuation coefficients** for up- and down-welling light



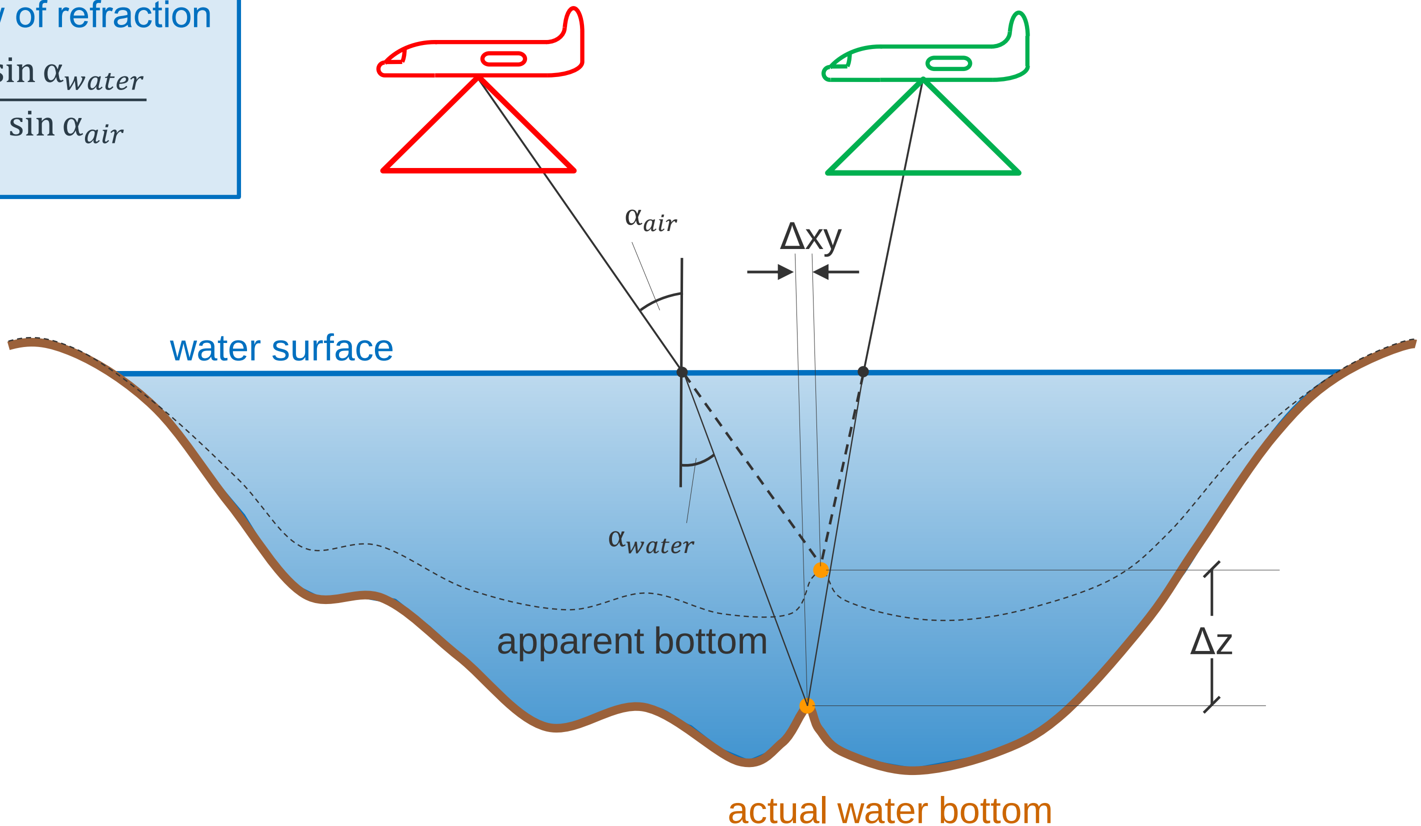
Istria/Croatien, Bay of Medulin, Data: Google Earth

Modifications
- Sun glint r ... nga et al, 2006)
- *h* from line ... Lyzenga, 1985)
- *h* from an
- Sophistica ... er, 2016)

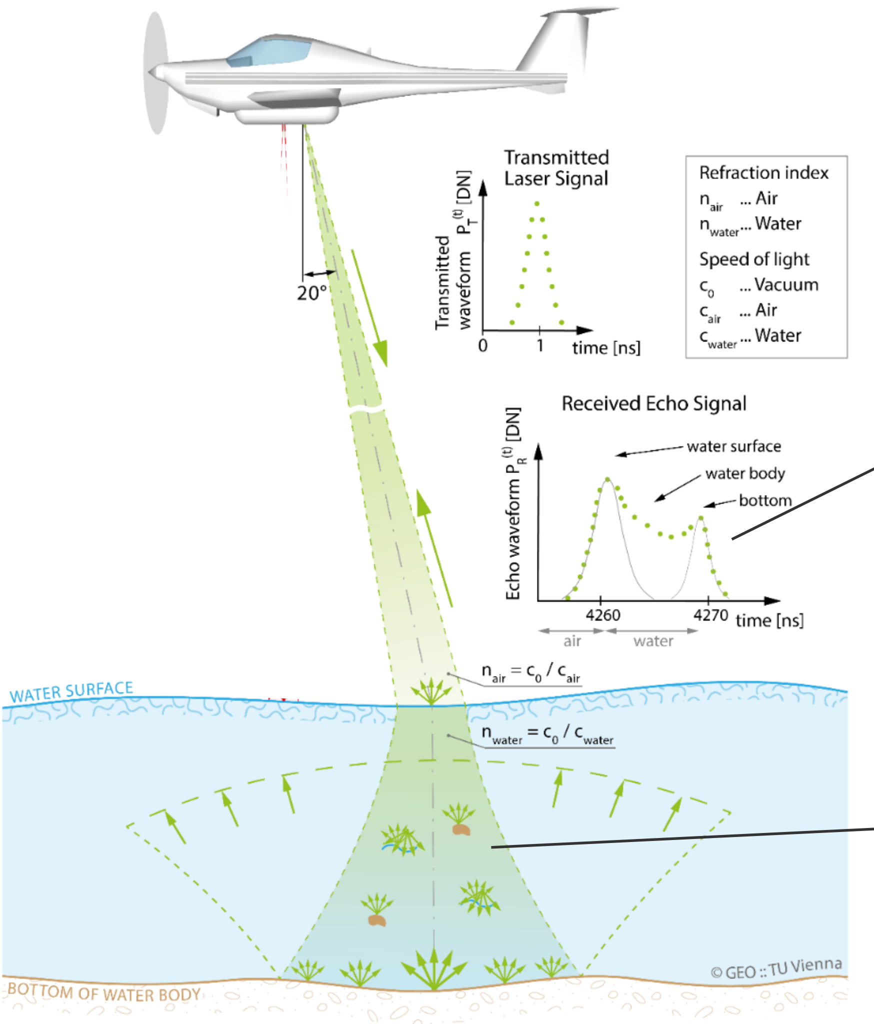
# Refraction correction: photo bathymetry

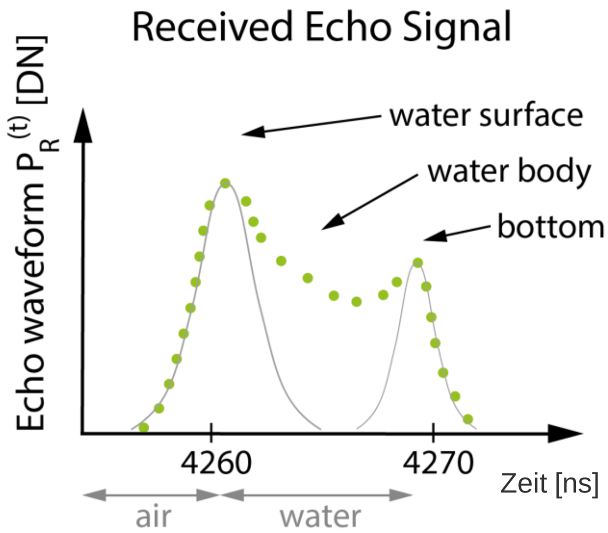
Snell's law of refraction

$$\frac{n_{air}}{n_{water}} = \frac{\sin \alpha_{water}}{\sin \alpha_{air}}$$



# Airborne Laser Bathymetry




Reflection at the water surface

Attenuation of light in water

- Absorption
- Scattering
    - Forward
    - Backward