Simulation and validation of underwater scenes for two-media optical 3D reconstruction

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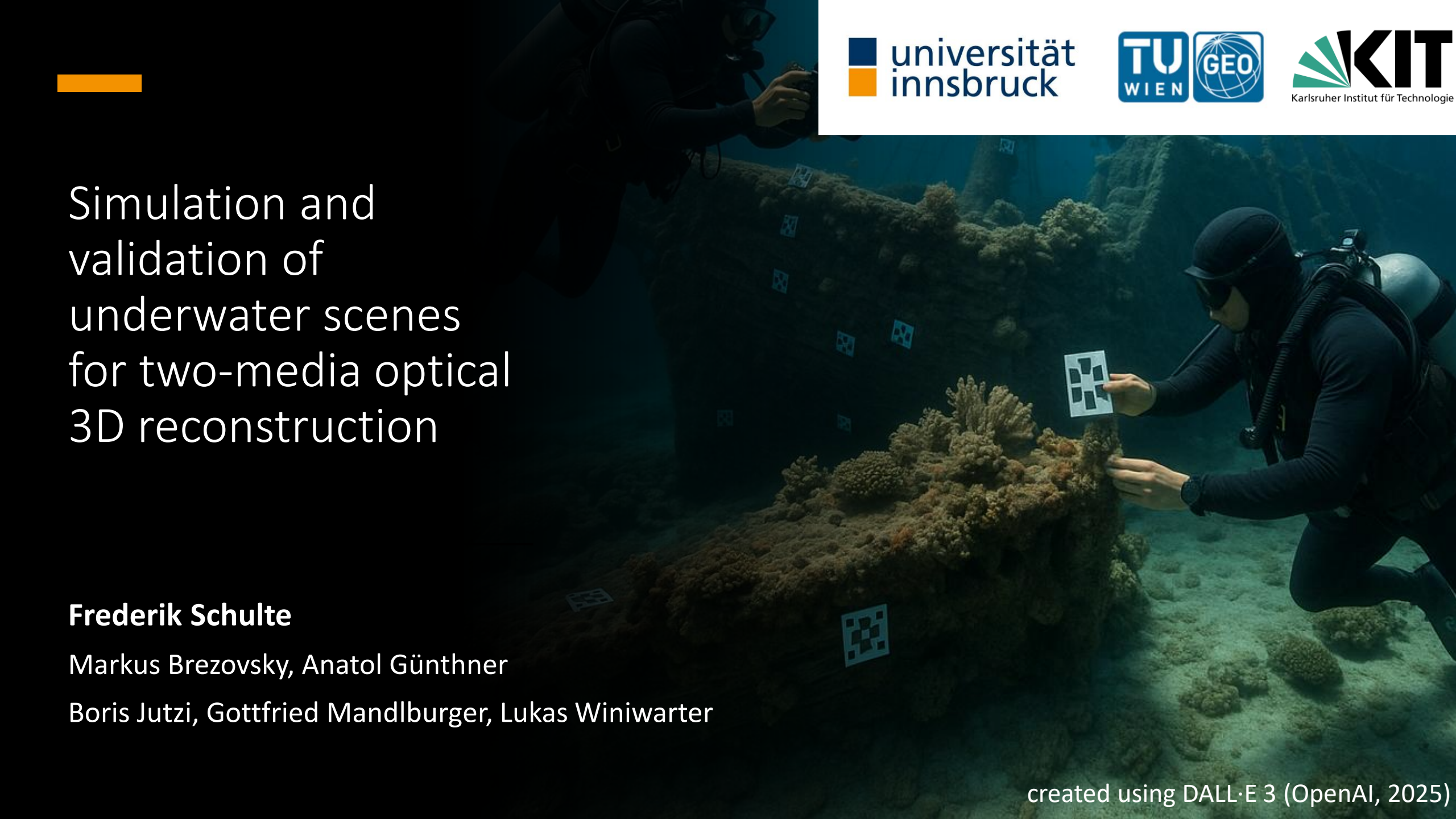
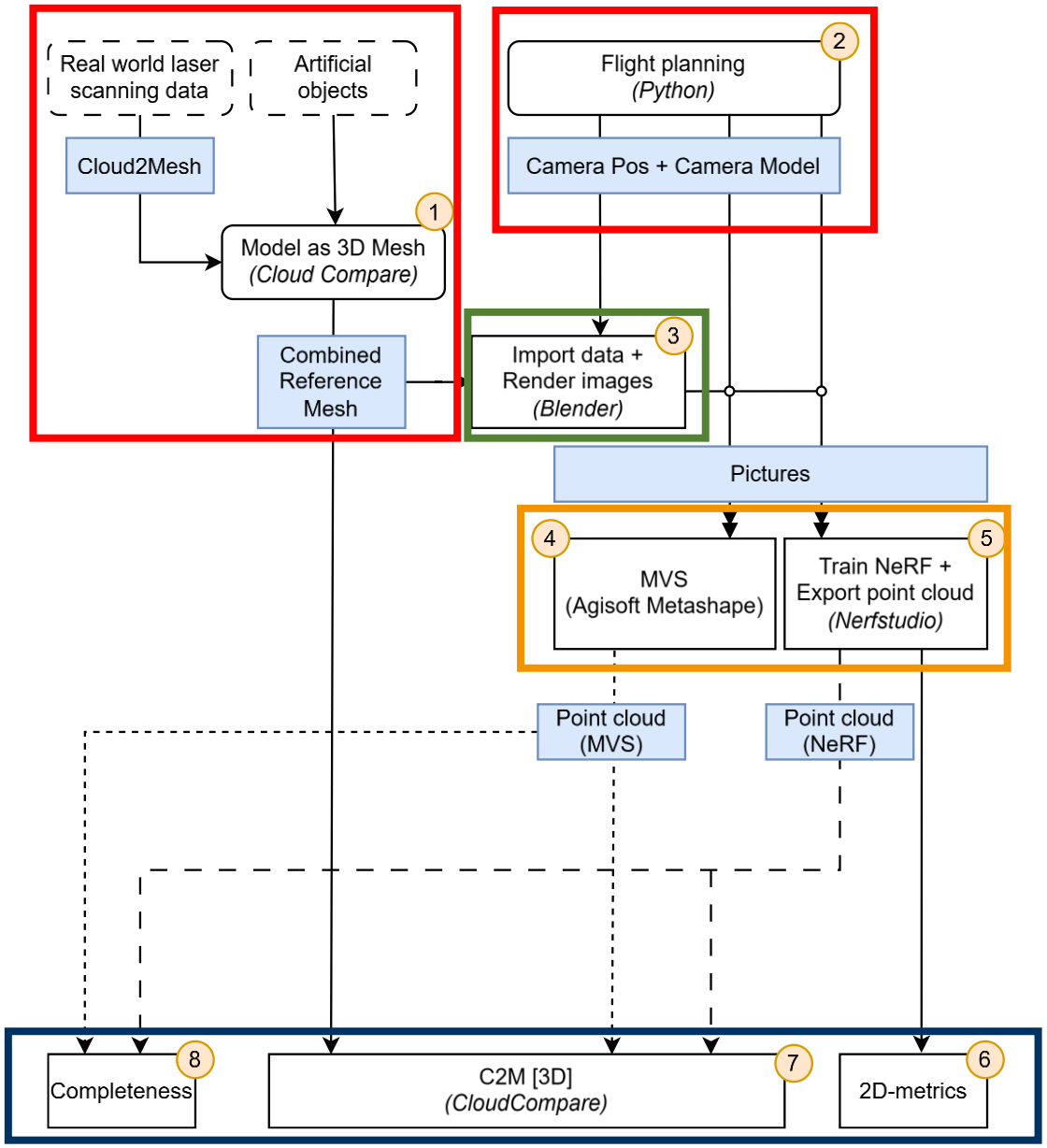


created using DALL·E 3 (OpenAI, 2025)

Workflow Simulation

1. Reference Data
2. Simulation of the scene
3. Data processing
4. Evaluation



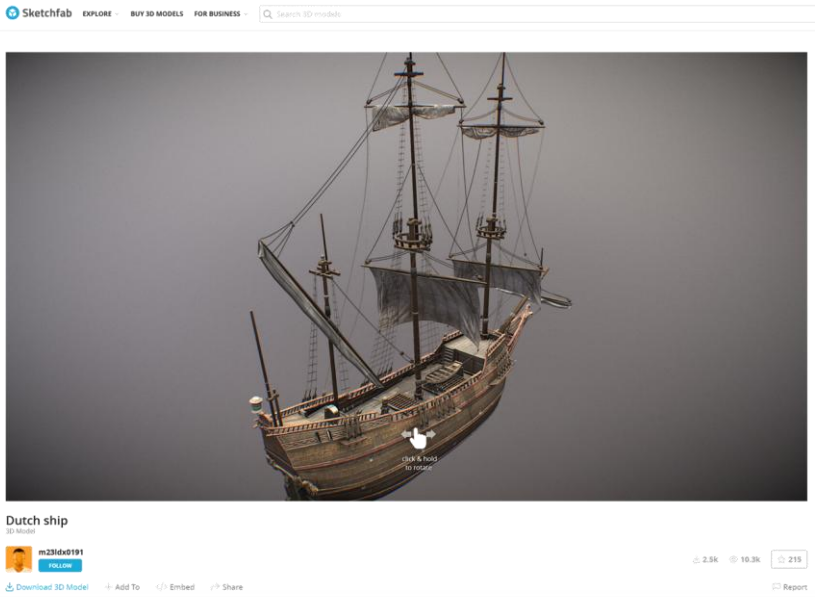
1. Reference Data

A: Combined Reference Mesh

- ULS data from Jamtal (ground)
- Synthetic ship geometry
- *Combination of synthetic and real data*

B: Cameras

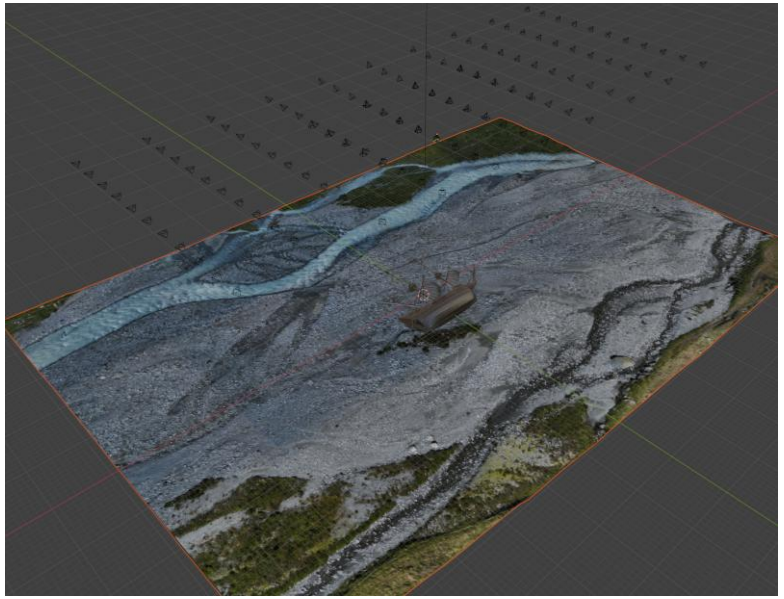
- Exterior orientation (X, Y, Z, ϕ, ω, κ)
- Camera model parameters
- Flight parameters

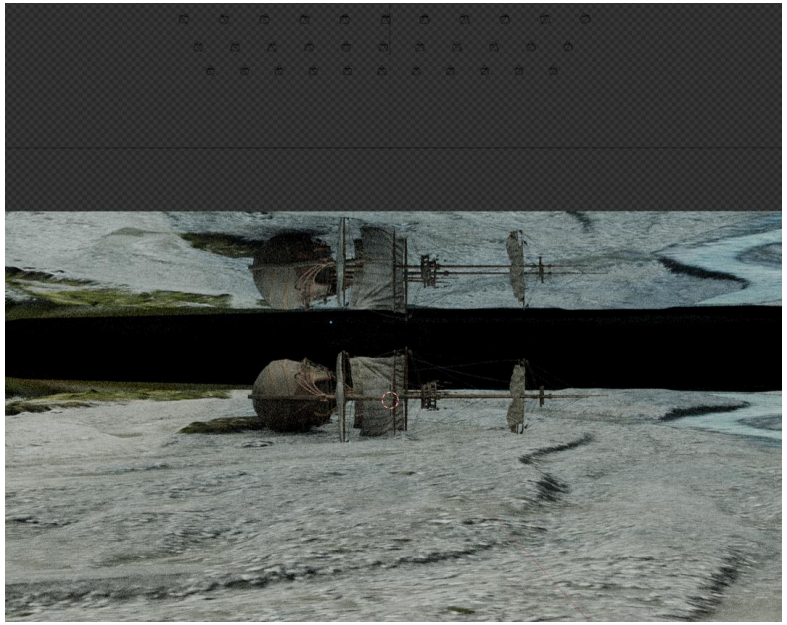


2. Simulation of scene

Blender (3D scene → 2D images)

1. Import reference mesh
2. Import cameras
3. Set up lighting
4. **Render images (no water dataset)**
5. Add water to scene
6. **Render images (water dataset)**





3. Data processing

Input:

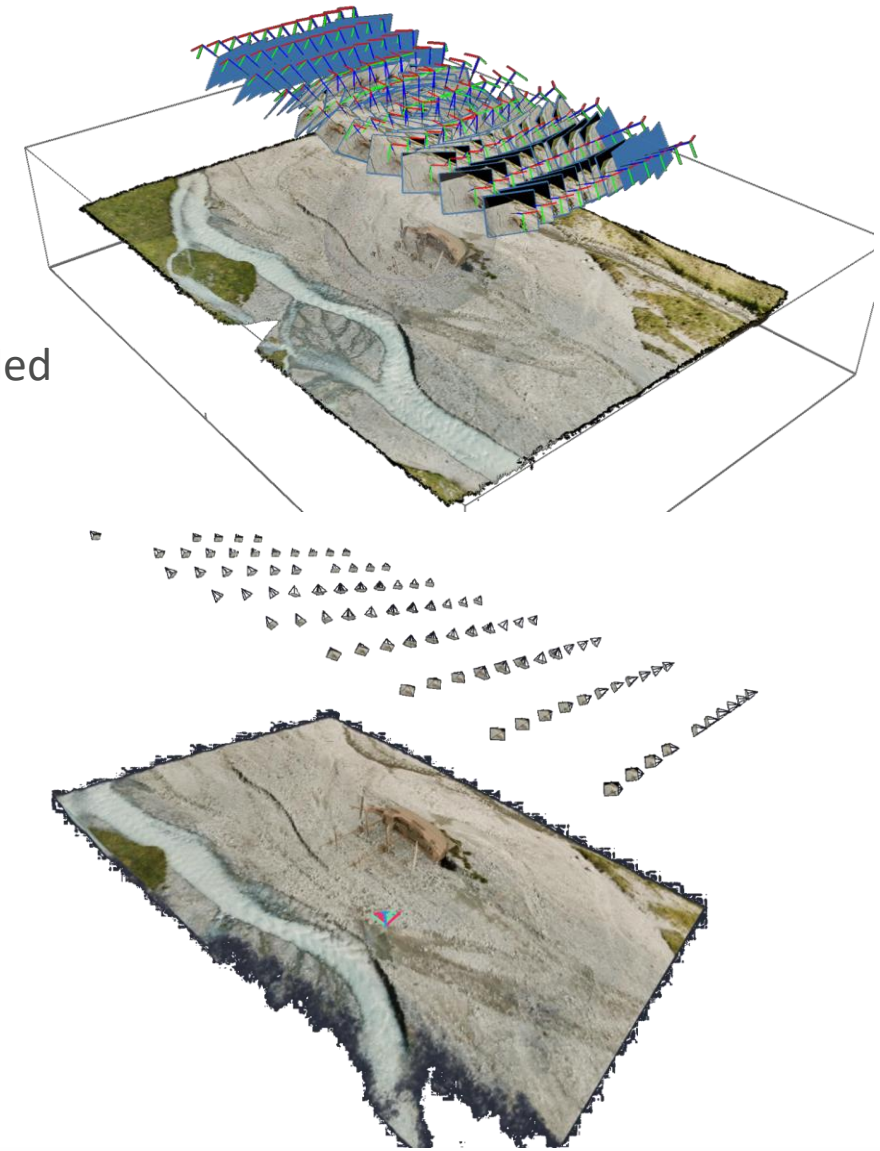
- Camera import based on reference values (1)
- Image import from Blender (2)
  - No in-situ camera calibration → optical distortions not modeled

Methods:

- MVS (Metashape)
- NeRF (Nerfstudio)
  - Training and exporting as point cloud

Result:

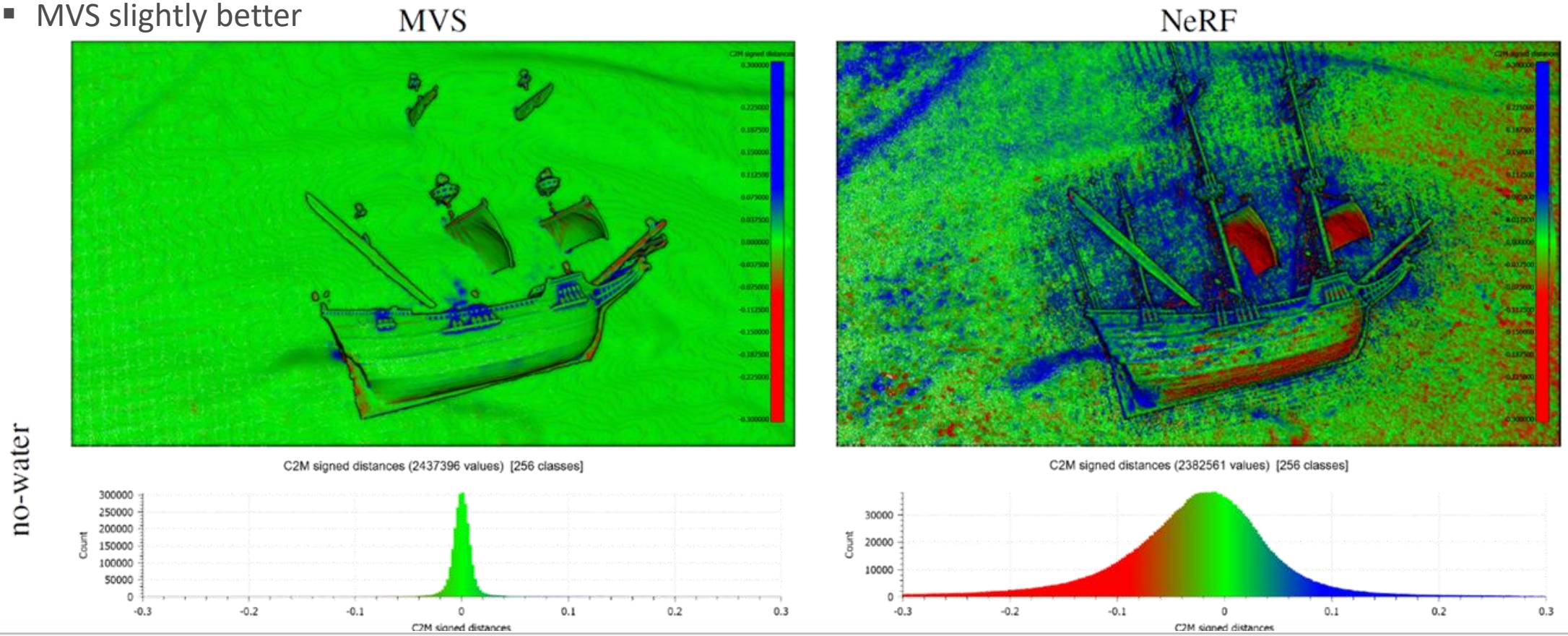
- 4 point clouds (2 x water + 2 x no water) ~ 2.5 Mio points
- Same CRS → No further registration required



4. Evaluation - Cloud to Mesh distances

No-water dataset:

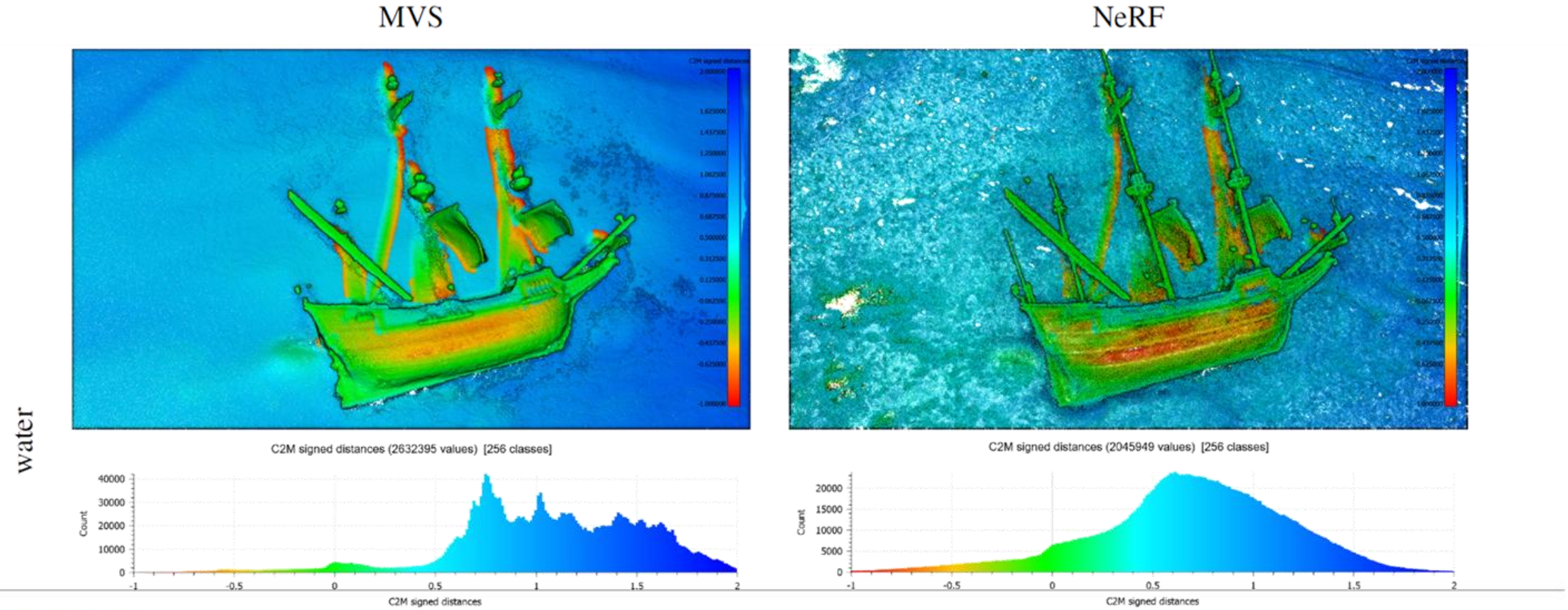
- High-quality reconstruction achieved
- MVS slightly better



4. Evaluation - Cloud to Mesh distances

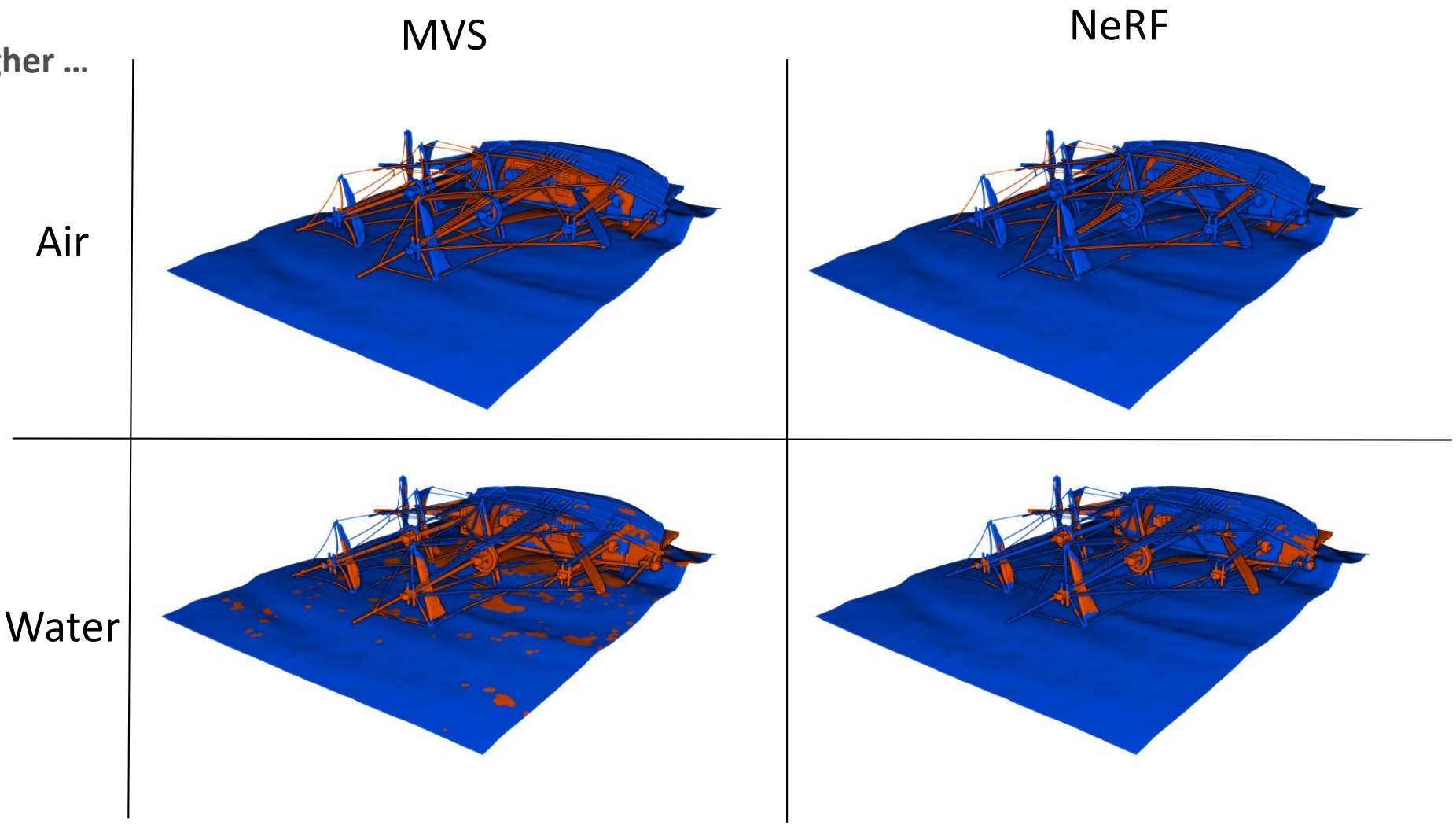
Water dataset:

- Mean deviations ~ 1 m → **Refraction effects must be taken into account in underwater reconstruction**



4. Evaluation - Completeness

- **Completeness was higher …**
  - In air scene
  - Using NeRFs



Results

- NeRFs performed better than MVS
- Refraction significantly affects reconstruction accuracy
- **Refraction-aware “geodetic” NeRFs are needed**
  - Main focus is on generating accurate and complete point clouds

Research project BathyNeRF

- Radiance field-based detection and 3D modeling of:
  - underwater topography
  - submerged vegetation

- **The following two presentations will cover the current project status**