# Title: Permanent Laser Scanning and 3D Time Series Analysis for Geomorphic Monitoring

**Detailed title:** Permanent Laser Scanning and 3D Time Series Analysis for Geomorphic Monitoring using Low-Cost Sensors and Open Source Software

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**Site specific:** No

## 1. Objective of assignment

The assignment's objective is to setup a permanent laser scanning (PLS) system using low-cost sensors and open-source software for the automatic near-continuous observation of topographic surface dynamics. PLS, i.e. the acquisition of 3D point clouds from a fixed position at high repetition frequency (e.g., hourly intervals), has become an important observation strategy to cover detailed spatiotemporal scales in geomorphic monitoring (e.g., Schröder et al. 2023, Vos et al. 2022). To increase the accessibility of this strategy, we want to investigate the potential of low-cost LiDAR sensors and compare the analysis to data acquired with high-end terrestrial laser scanning (TLS). An important part of the assignment will be to pre-process the time series data (georeferencing, co-registration) and to perform change analysis with state-of-the-art methods (time series-based analysis).

The assignment consists of the following steps:

- **Step 1:** Planning and setup of a permanent laser scanning system and acquisition of reference data (TLS, GNSS)
- **Step 2:** Pre-processing of the 3D time series, notably georeferencing and co-registration (alignment of all epochs in the time series)
- **Step 3:** Change analysis using state-of-the-art methods (e.g., time series clustering, 4D objects-by-change, object-based approaches)
- **Step 4:** Accuracy assessment of the data and derived changes compared to high-end TLS point clouds
- **Step 5:** Interpretation and presentation of results regarding observed surface dynamics

The result will be a highly automated workflow of PLS data acquisition and analysis to be used by the geoscientific community for near-continuous topographic monitoring. The planned application of riverbank monitoring (see Section 3) will showcase the performance and value of the observation strategy and provide potential insight into river dynamics in an high-Alpine valley.

The approach used in the assignment is transferrable to different use cases of topographic monitoring and will therefore provide a workflow that can be used for a diverse range of applications in the future with high accessibility due to the use of low-cost sensors and open-source software.

## 2. Materials used for assignment

We will use a Livox Avia sensor for permanent laser scanning from a fixed position in an experimental monitoring setup. Additionally, a high-end TLS (Riegl VZ-2000i) and RTK-GNSS (Leica Viva) will be available for supplementary acquisitions, e.g., as reference data and for accurate georeferencing.
In case that field work is not possible (weather-dependent), PLS experiments can be performed indoors and a dense PLS dataset acquired of Alpine slope dynamics in the Vals valley (Schröder et al. 2023) is readily available for the assignment.

The following **software** will be used and should be installed on the student computer also **prior** to the Summer School:

- **CloudCompare:** Download and install from: http://www.cloudcompare.org/
- **GIS software:** preferably QGIS: https://qgis.org/en/site/forusers/download.html#
- **Python:** incl. numpy, matplotlib, scipy
    - We recommend using the setup of the E-TRAINEE online course: https://3dgeo-heidelberg.github.io/etrainee/software/software_python.html; the required packages, incl. py4dgeo, are contained in Module 3: etrainee_m3.yml).
    - Note: basic programming skills are recommended but not a prerequisite, hands-on experience will be gained in teamwork with the assignment group.
- **py4dgeo** Python library for change analysis in 4D point clouds: https://py4dgeo.readthedocs.io/en/latest/ (contained in the Python environment of E-TRAINEE module 3, if above installation instructions are used).

## 3. Test site description

We are planning to acquire data of the Rotmoos Ache, the river in the Rotmoos valley above Obergurgl (Fig. 1). It has been surveyed by different strategies in previous editions of the summer school (UAV photogrammetry, UAV LiDAR, TLS), but never at the spatiotemporal scale planned in this assignment.
As we will perform only experimental data acquisition during one field day (a permanent installation is not possible in this frame), it may be required that manual experimental changes to the scene are induced for developing the acquisition and analysis workflow. All experiments will be conducted in careful consideration of preserving this natural landscape.

*Figure 1: View into Rotmoos valley with the riverbed of Rotmoos Ache as tentative study site for permanent laser scanning experiments.*

## 4. Methods

Practical exercises will focus on PLS processing and geomorphic change analysis of 3D time series. Scripts for processing of the newly acquired data (incl. georeferencing and alignment to previous epochs, time series change detection) will be based on available material provided by the lecturers and using well-documented open-source tools.

## 5. Documentation

Document your methods and results in

- Powerpoint presentations
- A report, for which it is recommended to use the full paper templates (in Word or LaTeX) from: https://www.isprs.org/documents/orangebook/app5.aspx

## 6. Deliverables

At the end the Summer School, upload your data, final presentation and report to the Summer School repository. Together with your data, also upload a data description, following the Metadata Sheet in Appendix A.

## 7. Literature

Anders, K., Winiwarter, L., Mara, H., Lindenbergh, R., Vos, S. E., Höfle, B. (2021). Fully automatic spatiotemporal segmentation of 3D LiDAR time series for the extraction of natural surface changes. *ISPRS Journal of Photogrammetry and Remote Sensing*, *173*, pp. 297-308. doi: 10.1016/j.isprsjprs.2021.01.015.

Lague, D., Brodu, N., Leroux, J. (2013). Accurate 3D comparison of complex topography with terrestrial laser scanner: Application to the Rangitikei canyon (N-Z). *ISPRS Journal of Photogrammetry and Remote Sensing*, 82, pp. 10-26. doi: 10.1016/j.isprsjprs.2013.04.009.

Schröder, D., Anders, K., Winiwarter, L., Wujanz, D. (2023). Permanent terrestrial LiDAR monitoring in mining, natural hazard prevention and infrastructure protection–Chances, risks, and challenges: A case study of a rockfall in Tyrol, Austria. *5th Joint International Symposium on Deformation Monitoring (JISDM 2022)*, pp. 51-59. doi: 10.4995/JISDM2022.2022.13649.

Vos, S., Anders, K., Kuschnerus, M., Lindenbergh, R., Höfle, B., Aarninkhof, S., de Vries, S. (2022). A high-resolution 4D terrestrial laser scan dataset of the Kijkduin beach-dune system, The Netherlands. *Scientific Data*, *9*(1), 191. doi: 10.1038/s41597-022-01291-9.

## 8. Further information

Appropriate clothing, food and beverages for a day in the field are required.

## Appendix A: Metadata Sheet template

Authors:

Abstract: (short project description, max 100 Words)

Keywords:

Coverage: (Specify Latitude/Longitude, and Date/Time Start and Date/Time End)

Sensor(s):

Data format(s): (including data fields, for example .las files consisting of xyz and intensity)

List of data files: (including file sizes)

Remarks: (e.g., specifying software able to open the data files)