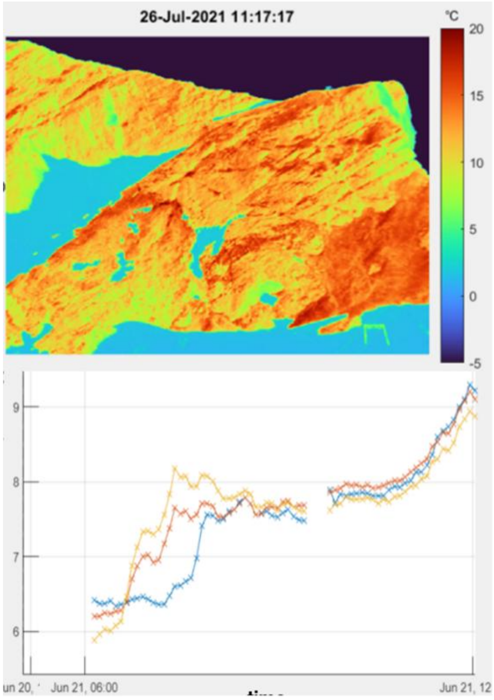
Professorship of Remote Sensing Applications
TUM School of Engineering and Design
Technische Universität München

Thesis

# Exploring Time Series Analysis Methods for Thermal Image Sequences in Permafrost Mountain Environments

Change analysis incorporating the full time series information has proven a valuable tool in understanding landscape dynamics, particularly in topographic studies interpreting 4D terrain development. The application of similar approaches to thermal imagery offers a promising avenue for characterizing environmental changes in permafrost environments in high-mountain regions, where temperature variability of rock material are critical indicators of climate impact.



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Remote sensing of surface temperatures over time can reveal microclimatic patterns, thaw cycles, and areas of thermal instability. However, practical challenges such as inconsistent imagery, atmospheric interference (e.g., fog/clouds), and registration inaccuracies complicate direct analysis. This project aims to explore how time series clustering, 4D object detection and temporal feature extraction techniques can be adapted and optimized for such thermal datasets, with the ultimate goal of enhancing our ability to detect and monitor permafrost-related changes.

This thesis aims to explore and adapt time series analysis methods, such as clustering (Kuschnerus et al., 2021) and 4D object extraction (Anders et al., 2021), for thermal imagery in permafrost mountain regions. The goal is to identify spatial and temporal patterns that may indicate surface temperature changes or instability. Additionally, the work will assess how data quality, such as cloud cover or registration issues, affects analysis outcomes. The use of corresponding RGB imagery will be considered to support interpretation and validation. Available data have been acquired by Lucks et. al (2023) with a permanent sensor installation at the Zugspitze mountain.

The student should have experience with topographic data and image processing, particularly in handling geospatial datasets. Basic programming skills are essential, preferably in Python, including familiarity with libraries for data analysis and visualization (e.g., NumPy, matplotlib, scikit-learn). Prior knowledge of time series analysis or thermal imaging is beneficial but not mandatory. A structured and independent approach to working with incomplete or noisy datasets is also important.

Supervision: Prof. Dr. Katharina Anders, Contact: k.anders@tum.de

### References

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*, 297-308.

Kuschnerus, M., Lindenbergh, R., & Vos, S. (2021). Coastal change patterns from time series clustering of permanent laser scan data. *Earth Surface Dynamics*, *9*(1), 89-103.

Lucks, L., Gaisbauer, S., Scandroglio, R., Hoegner, L., & Stilla, U. (2023). Multitemporal clustering of thermal images for analysis of permafrost occurrence in steep rock walls. In *6th VAO Symposium*.