Tracing Snow Cover Dynamics Using 4D Level-Sets on Near-Continuous Terrestrial Laser Scanning Time Series

Reuma Arav, Florian Pöppl

Dept. of Geodesy and Geoinformation,

TU Wien, Austria

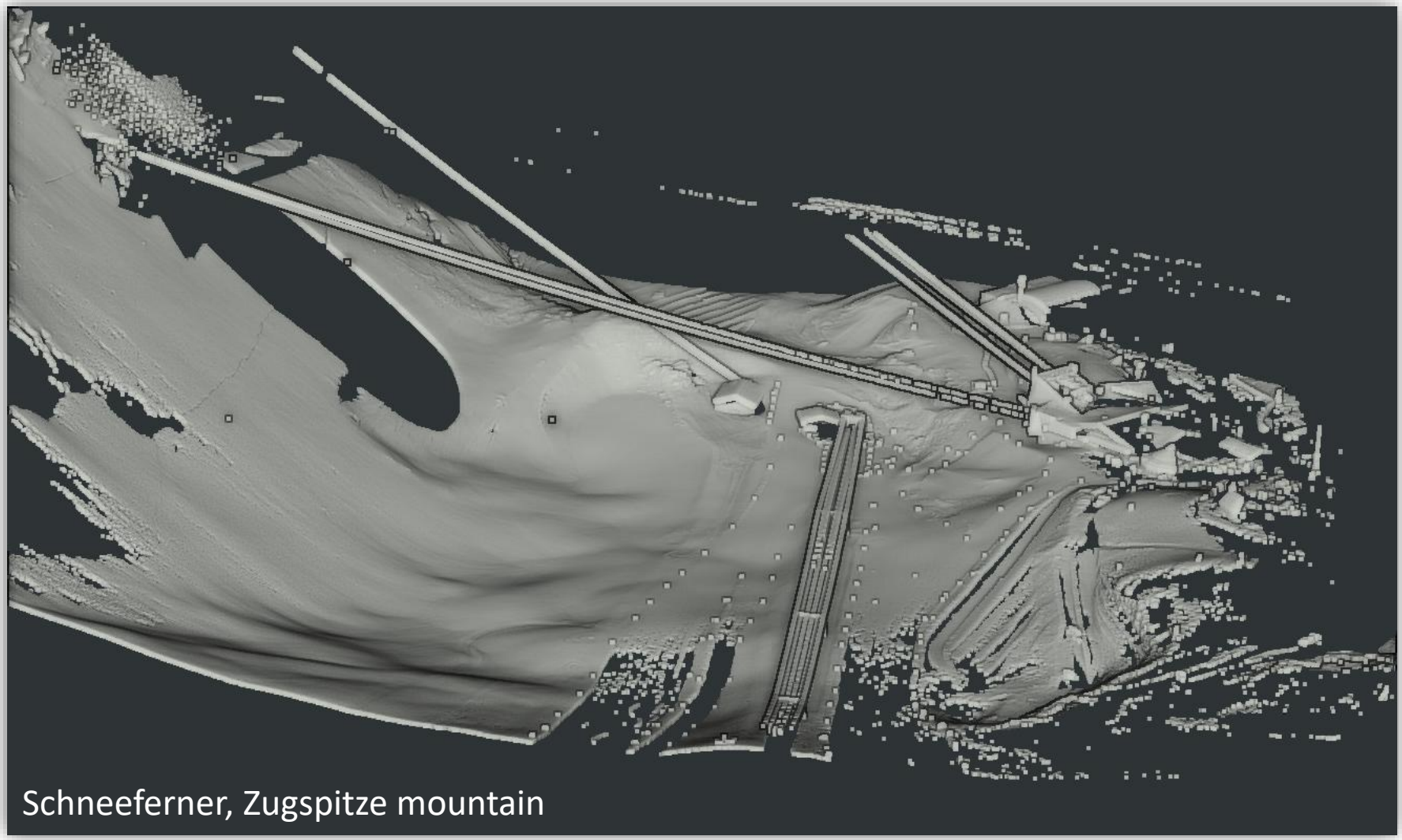
Katharina Anders, Bernhard Höfle

Institute of Geography,

Heidelberg University,

Germany

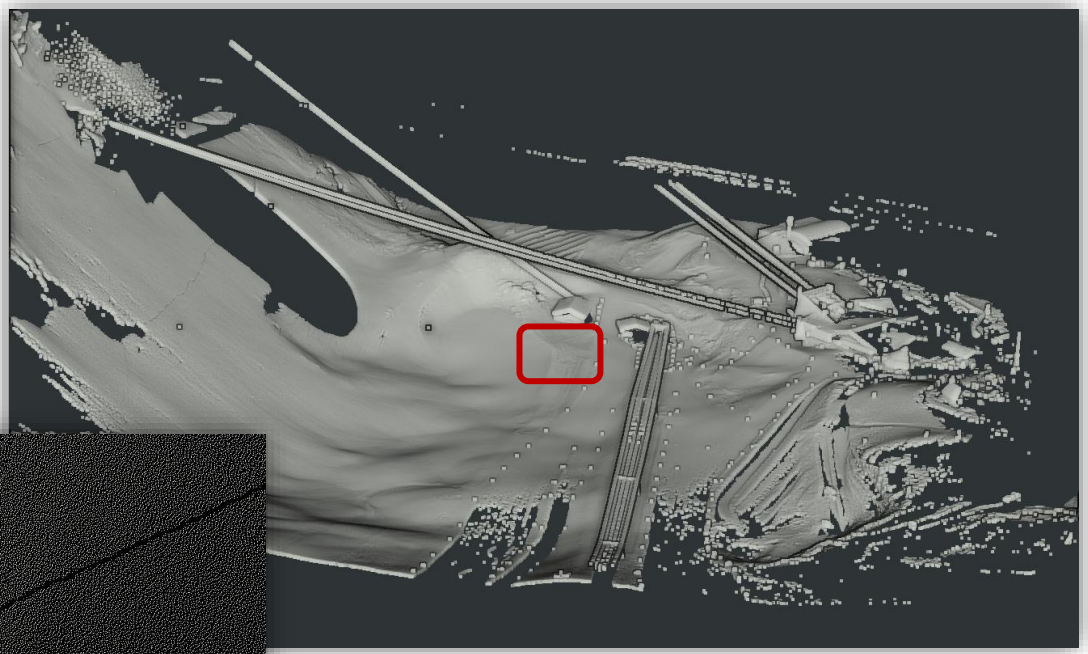
Monitoring through point clouds



Schneeferner, Zugspitze mountain

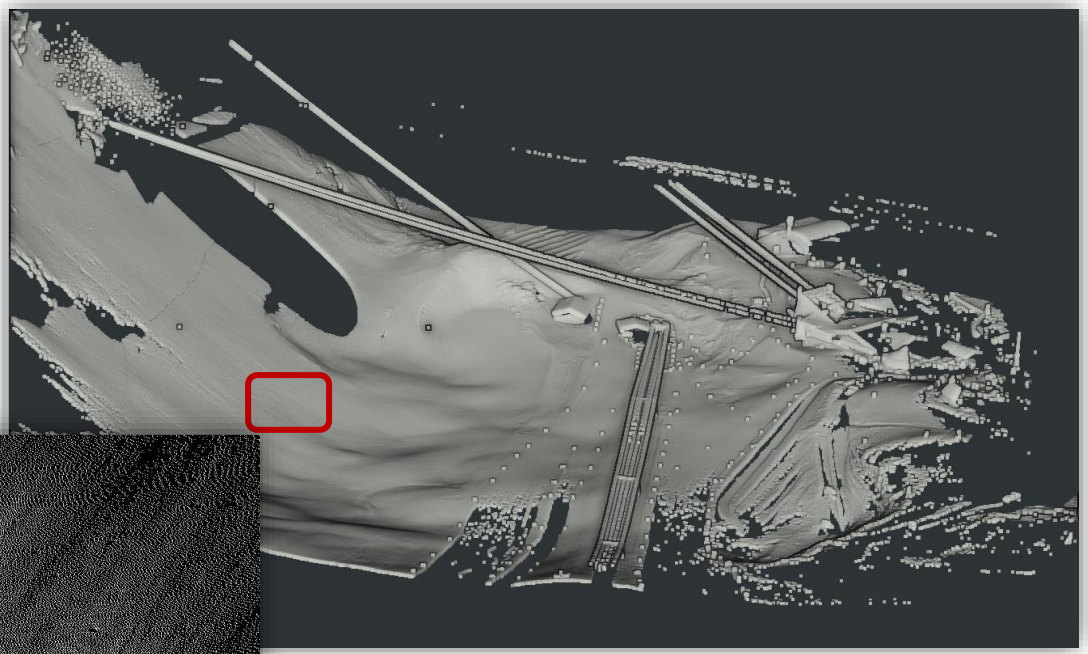
Monitoring through point clouds

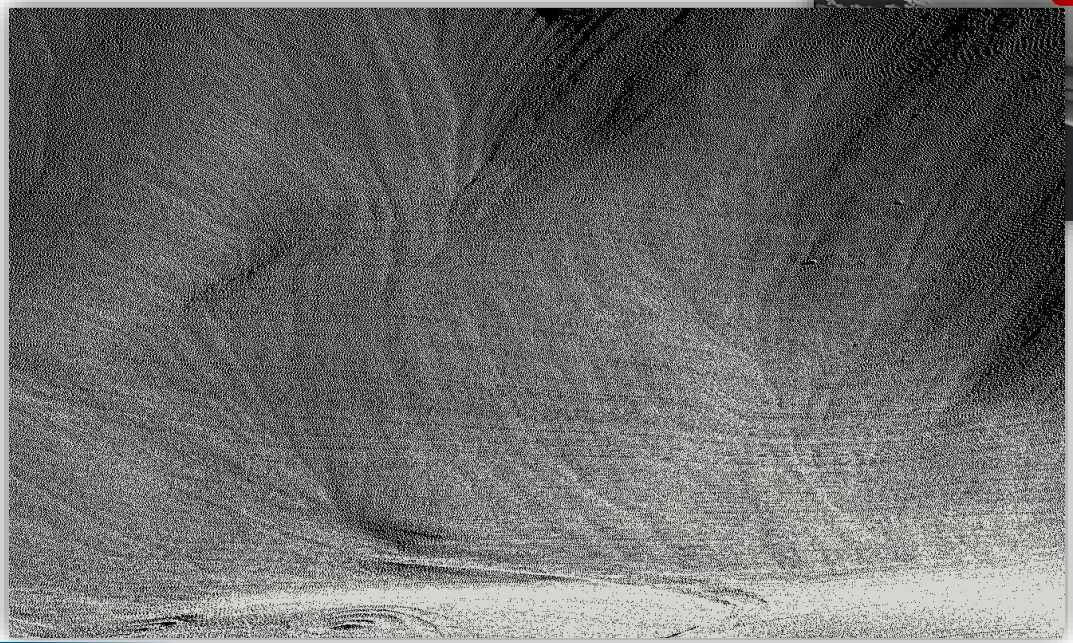
- Level of detail



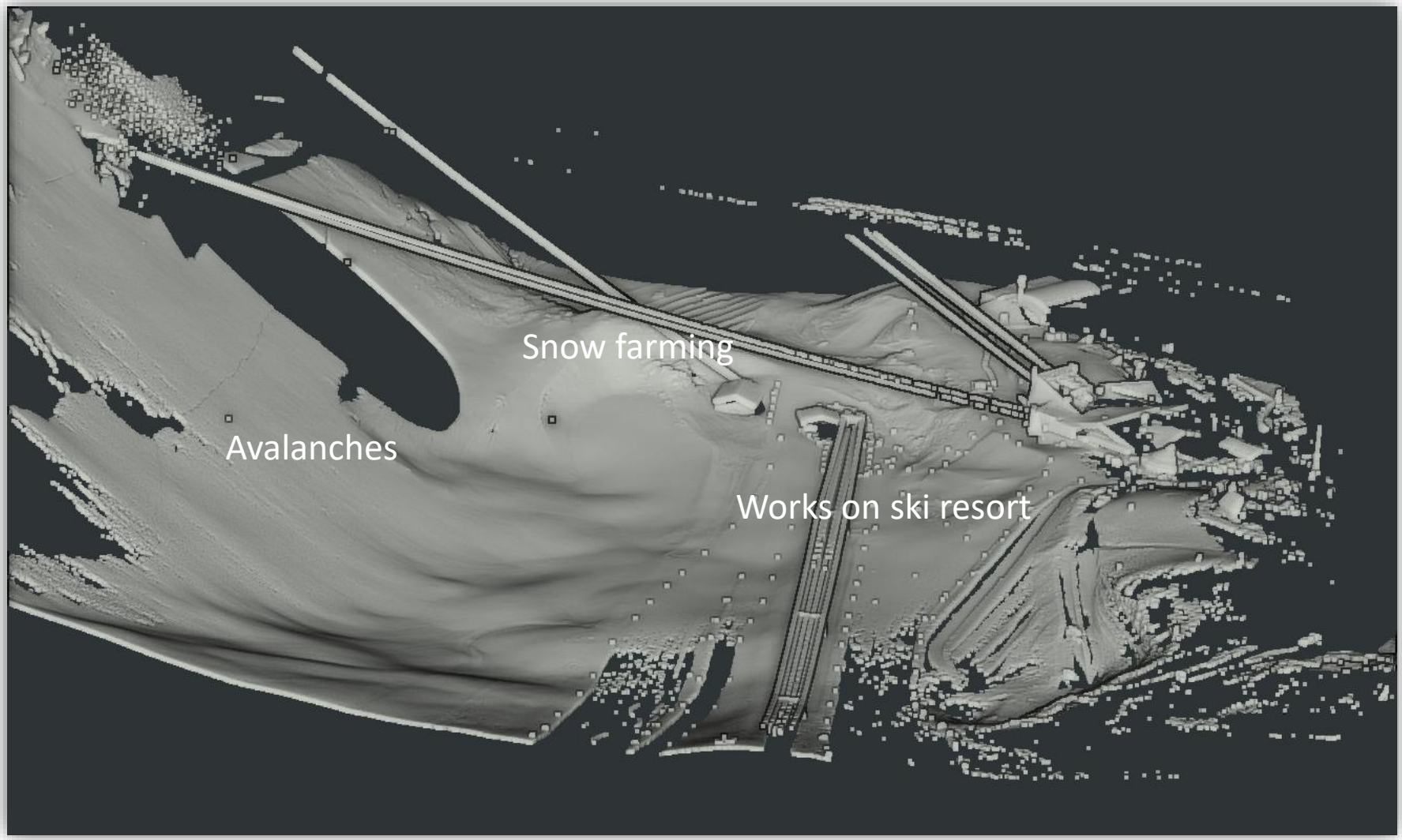
Monitoring through point clouds

- Level of detail





How do we monitor dynamic processes?



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MorE3D

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Monitoring dynamic processes

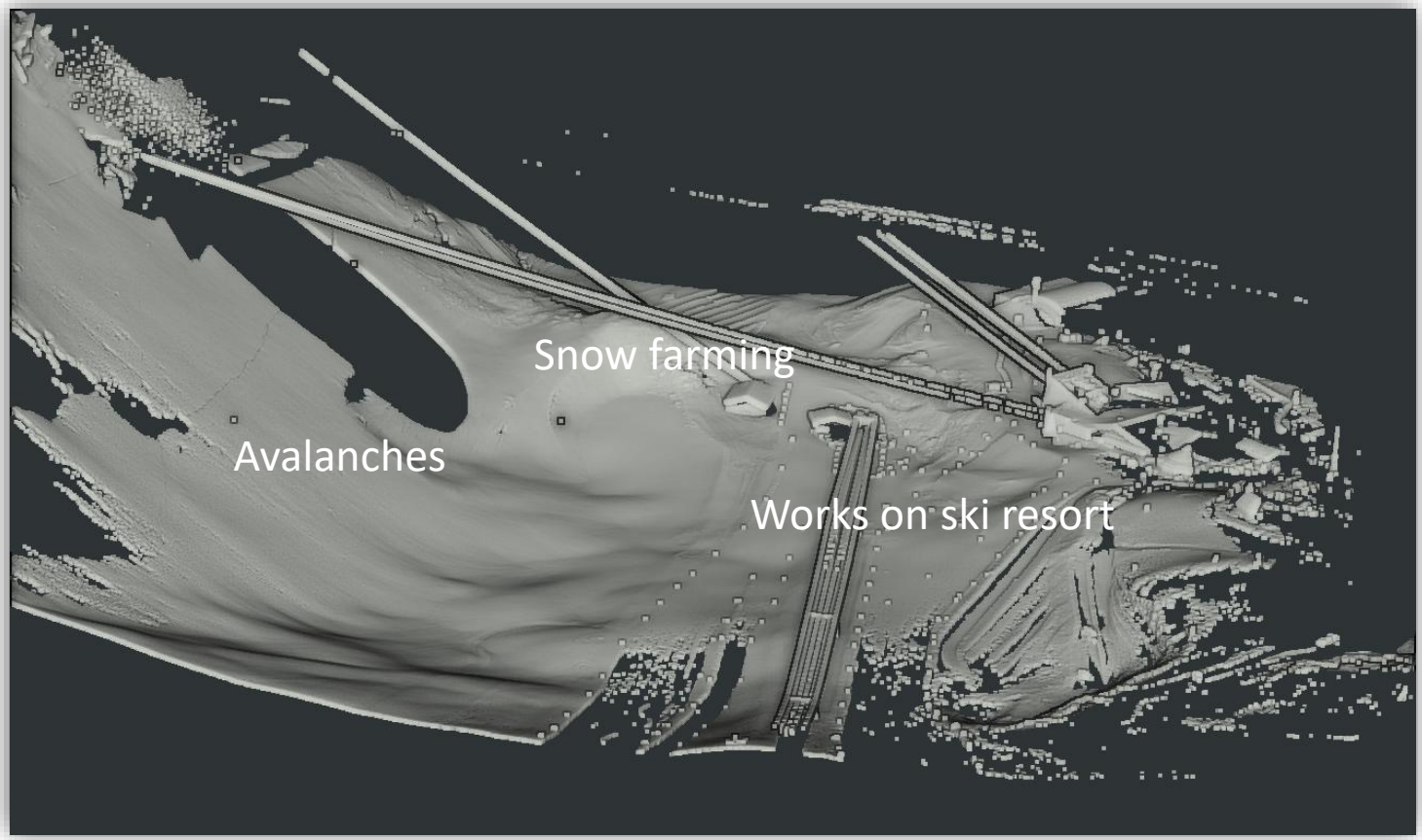
- Data characteristics
  - Data volume
  - Unorganized
- Phenomena characteristics
  - Embedded within the surface
  - Constantly changing
- Multi-epoch monitoring
  - Frequency
  - Fixed points are not always possible

Monitoring dynamic processes

- Near-continuous laser scanning
  - Hourly scan
    - 17-22 April, 2018
    - 47°24’ 59”N, 10°58’46”E
  - Angular resolution: 0.017°
  - Two scanning positions
    - Day and night
    - Mean registration accuracy: 2.5 cm

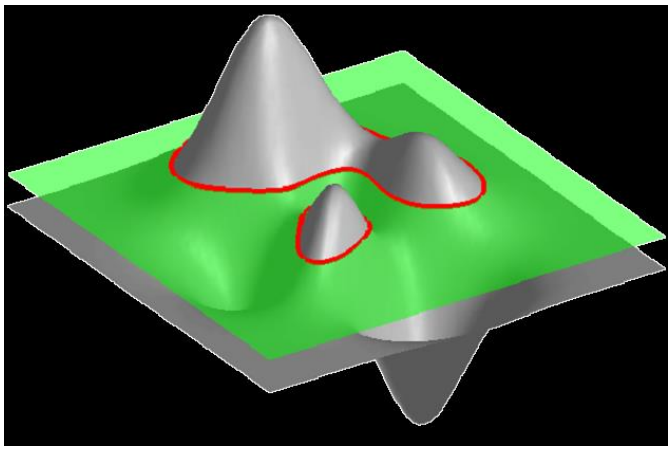
Monitoring dynamic processes

- How do we monitor dynamic processes?
  - Multiple processes at the same time



Level set method as the solution

- Data driven
  - Little adaptation between domains
- Topologically flexible
- Can be easily extended
  - Constraints



Level set method as the solution

- Define boundaries as a continuous curve
  - The curve is represented implicitly $C = \{\mathbf{x} \mid \phi(\mathbf{x}) = 0\}; \quad \mathbf{x} = (x, y)$

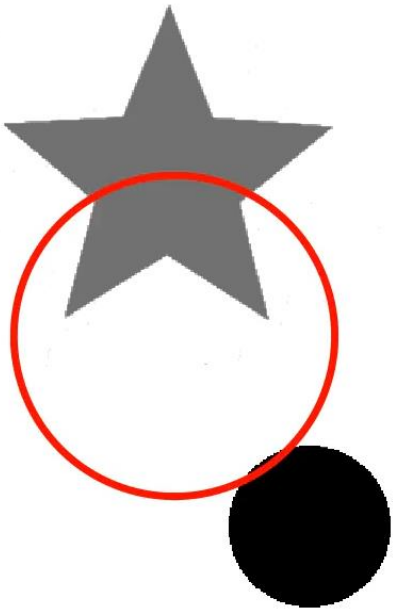
- Look for homogeneity inside and outside the curve
  - According to some cues ξ

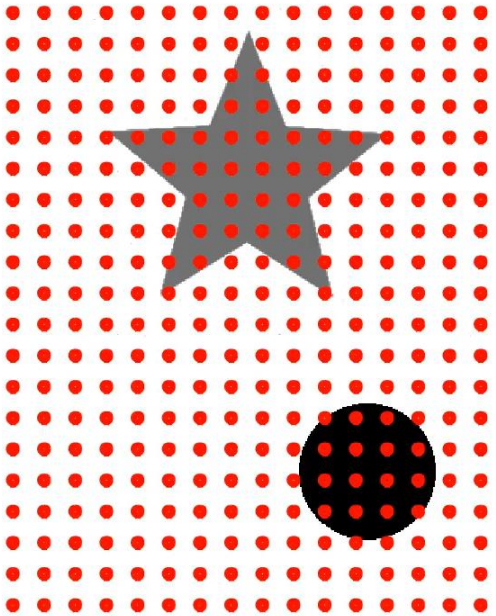
$$E(\mathcal{C}, \bar{\xi}_{in}, \bar{\xi}_{out}) = \mu_1 \int_{\Omega_{in}} \left|\xi(\mathbf{x}) - \bar{\xi}_{in}\right|^2 d\mathbf{x} + \mu_2 \int_{\Omega_{out}} \left|\xi(\mathbf{x}) - \bar{\xi}_{out}\right|^2 d\mathbf{x} + \nu_0 \cdot |\mathcal{C}|$$

  - Ensures smooth and continuous delineation
  - Little dependence on initialization
  - Iterative solution

Level set method as the solution

- Ensures smooth and continuous delineation
- Little dependence on initialization
- Iterative solution

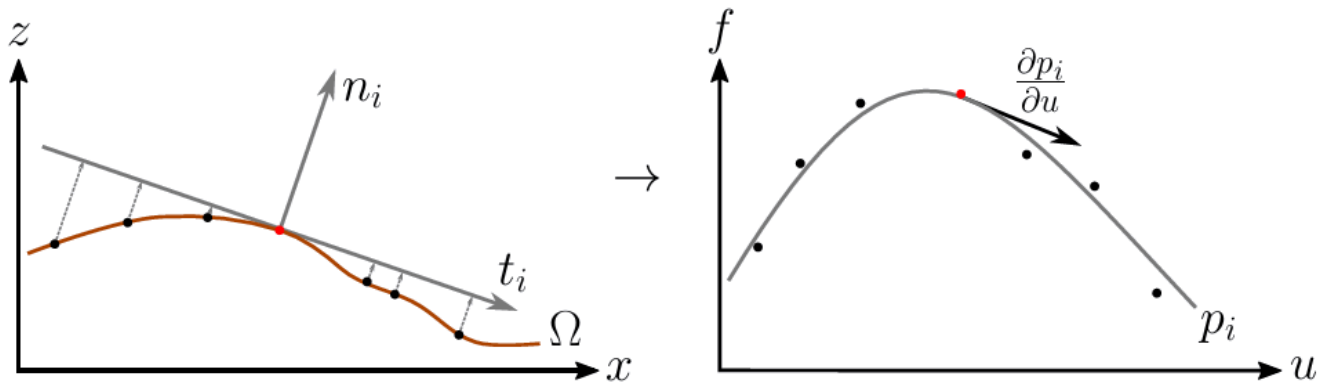




Adaptation of the level-set to 3D detection

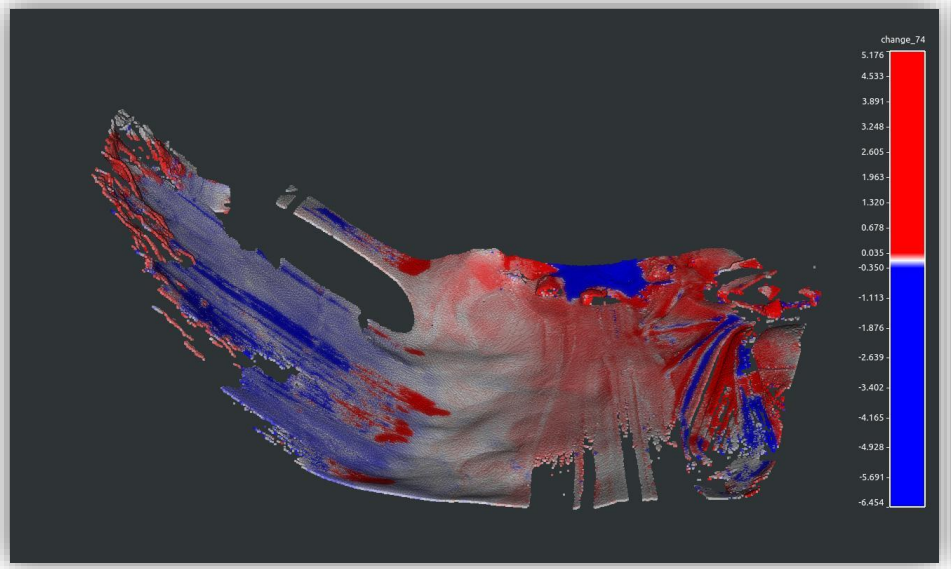
- Consider the point cloud as a discrete samples of the surface

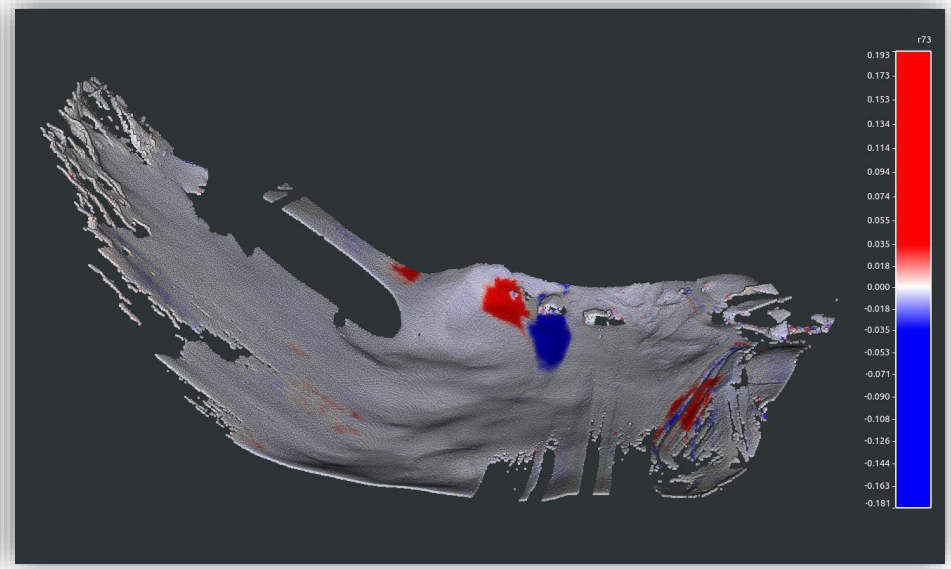
- Approximated surface derivatives
  - Least-squares polynomial fit in the tangent plane
  - Projection of the neighboring points to the tangent plane



Finding 3D changes

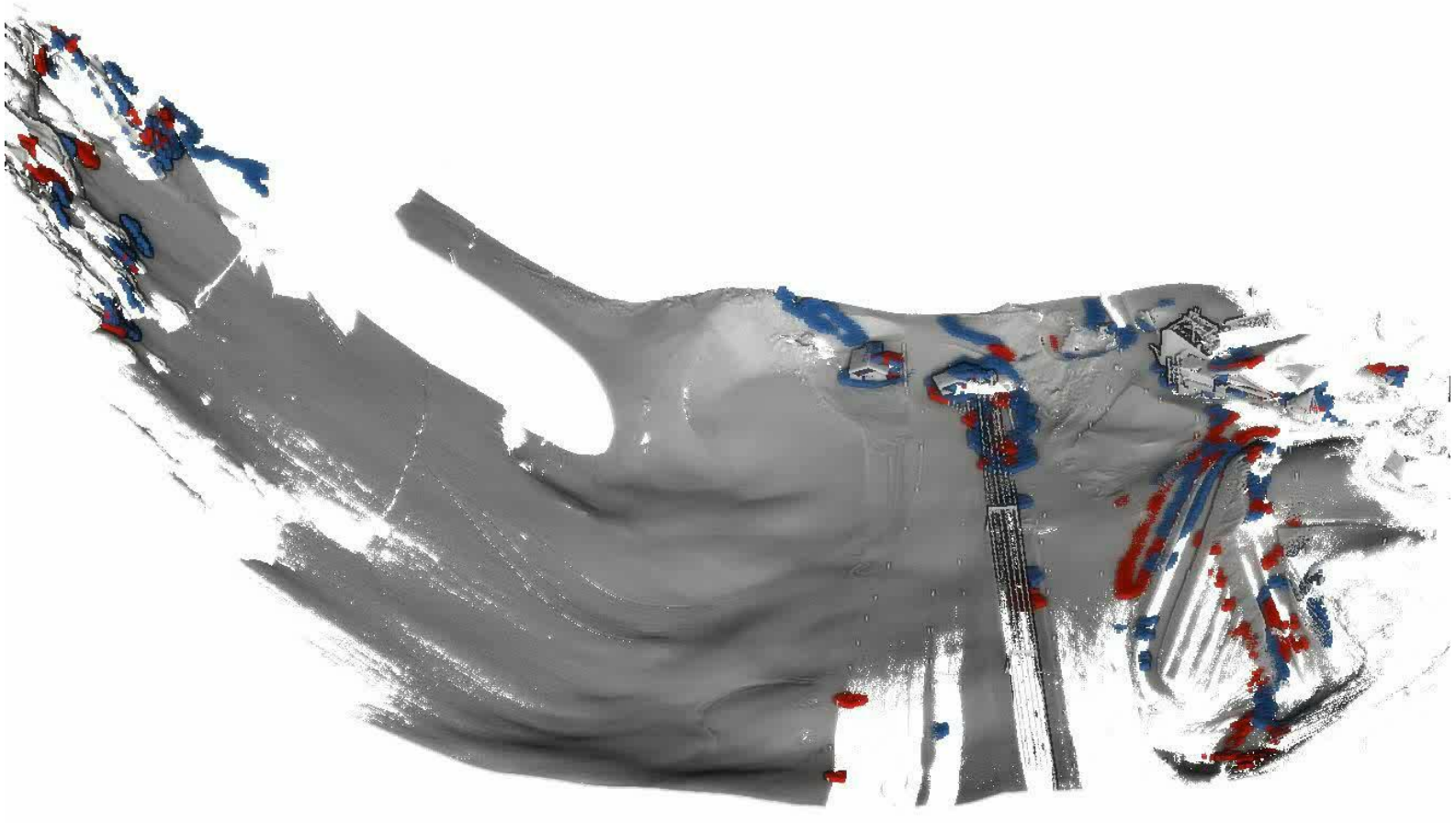
- Cues
  - A single phenomenon can share
    - same change magnitude
    - same change rate





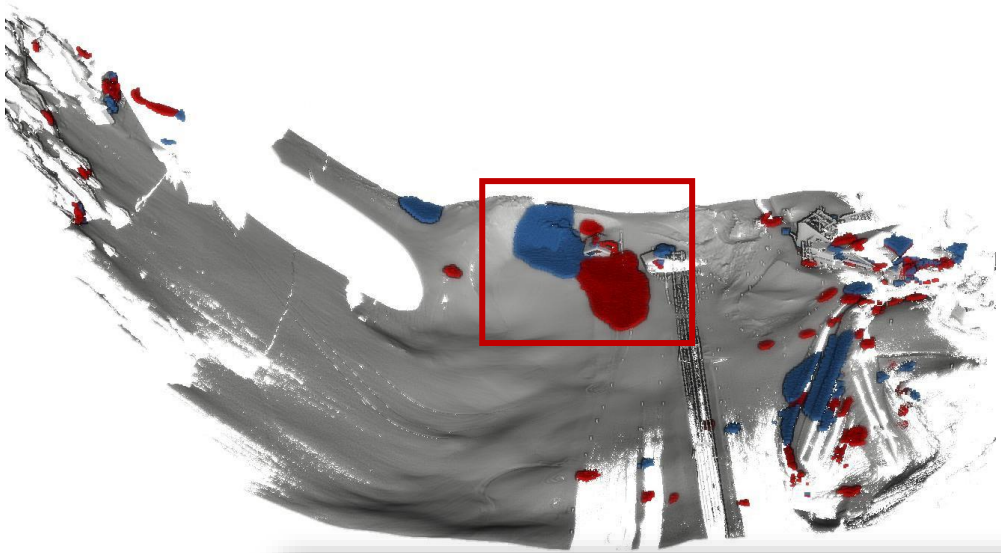
Detection using change rate

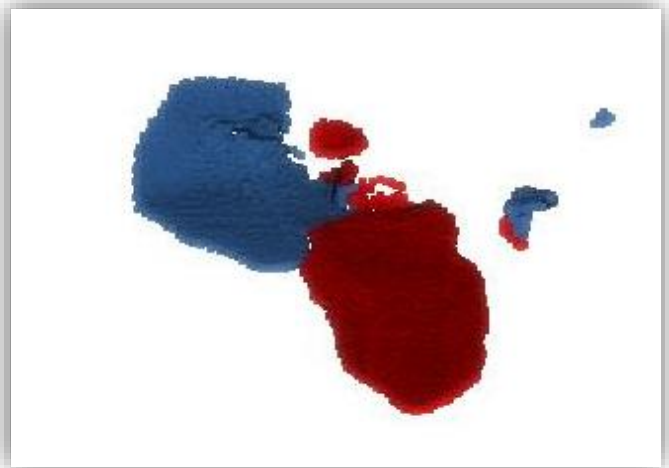
Rate: 24 hours

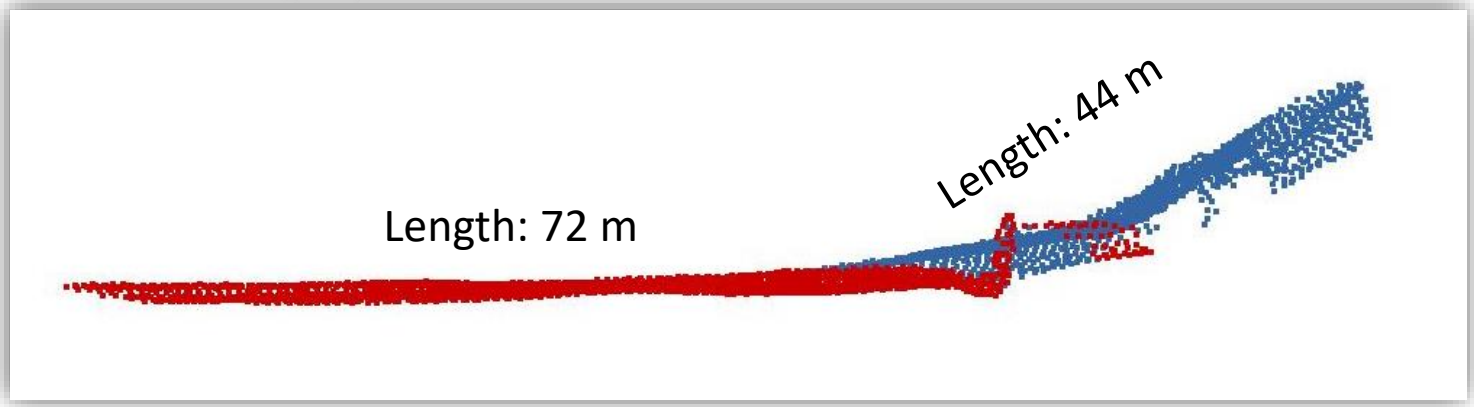


Level of detection 3.5 cm

Geometric characterization of the change







Rate 24 hours, epoch 74

Conclusions

- Simultaneous extraction across multiple epochs
  - A single analysis process
- No preliminary information
  - No number or type needed
- Easy change characterization

Outlook

- Quantitative quality assurance
  - Previous experiments: 85%-92%[1]
  - Manual delineation
- Overlapping phenomena detection
  - Time series analysis

[1]Arav, R., & Filin, S. (2022). A visual saliency-driven extraction framework of smoothly embedded entities in 3D point clouds of open terrain. *ISPRS J.*, 188, 125-140. https://doi.org/10.1016/j.isprsjprs.2022.04.003

Openly available sources

- Code:
  - https://github.com/TUW-GEO/MorE3D

    (Or just look for MorE3D on Github)

- Dataset:
  - Anders, Katharina; Eberlein, Stefan; Höfle, Bernhard (2022):

    Hourly Terrestrial Laser Scanning Point Clouds of Snow Cover in the Area of the Schneeferner, Zugspitze, Germany. PANGAEA, https://doi.org/10.1594/PANGAEA.941550

Thank you!

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