



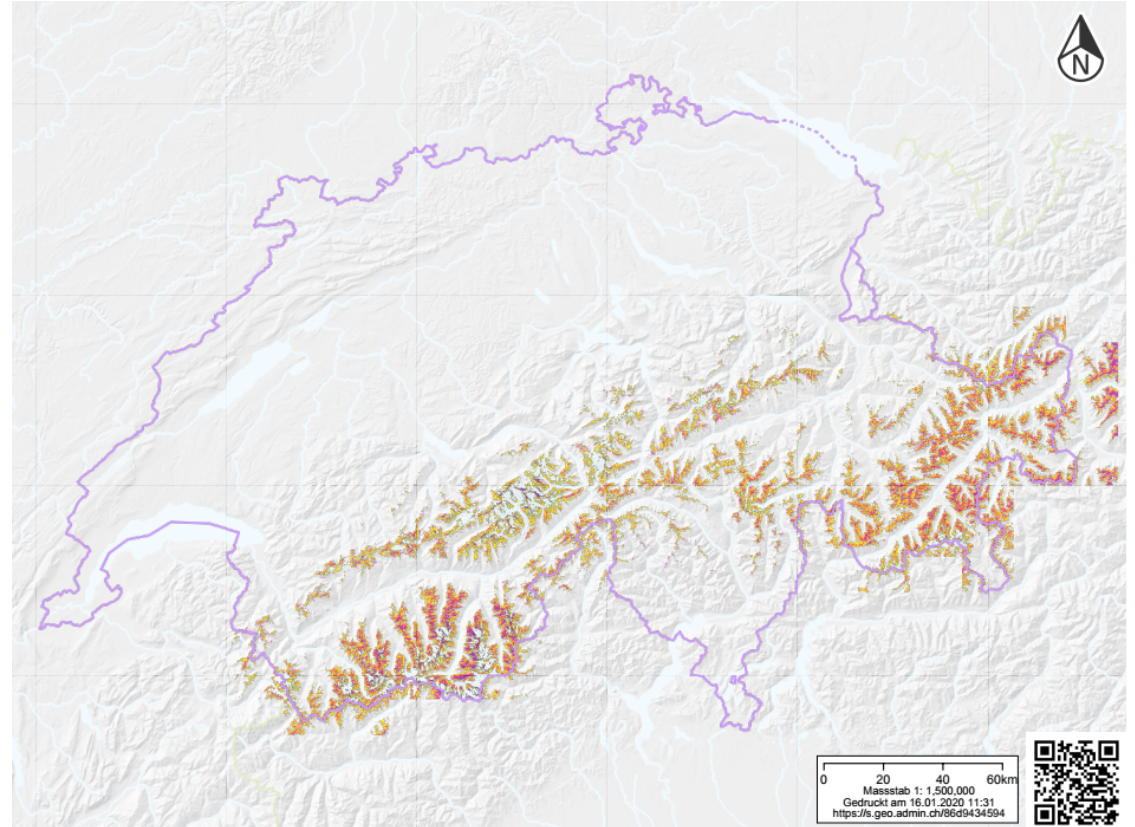
Monitoring Climate Change at the Edge of the Cloud

Matthias Meyer

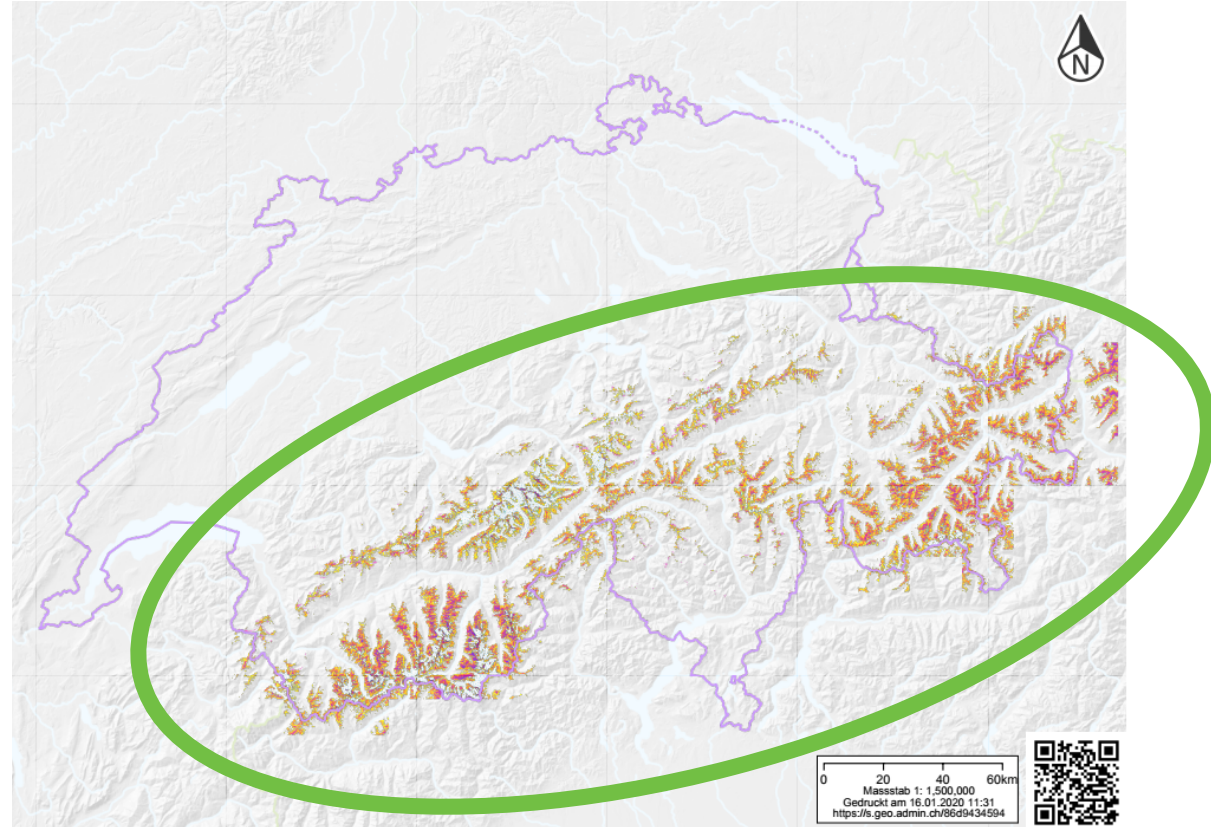
Computer Engineering Group

ETH zürich

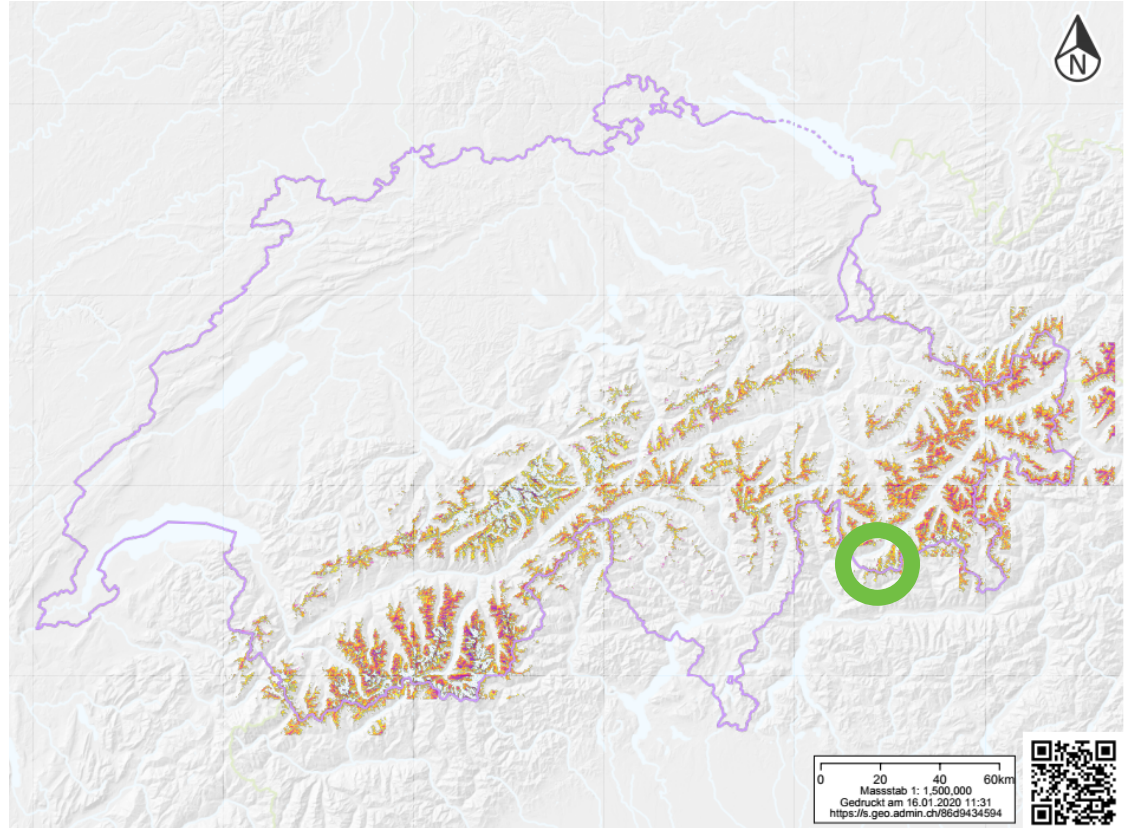
Climate Change in the Swiss Alps



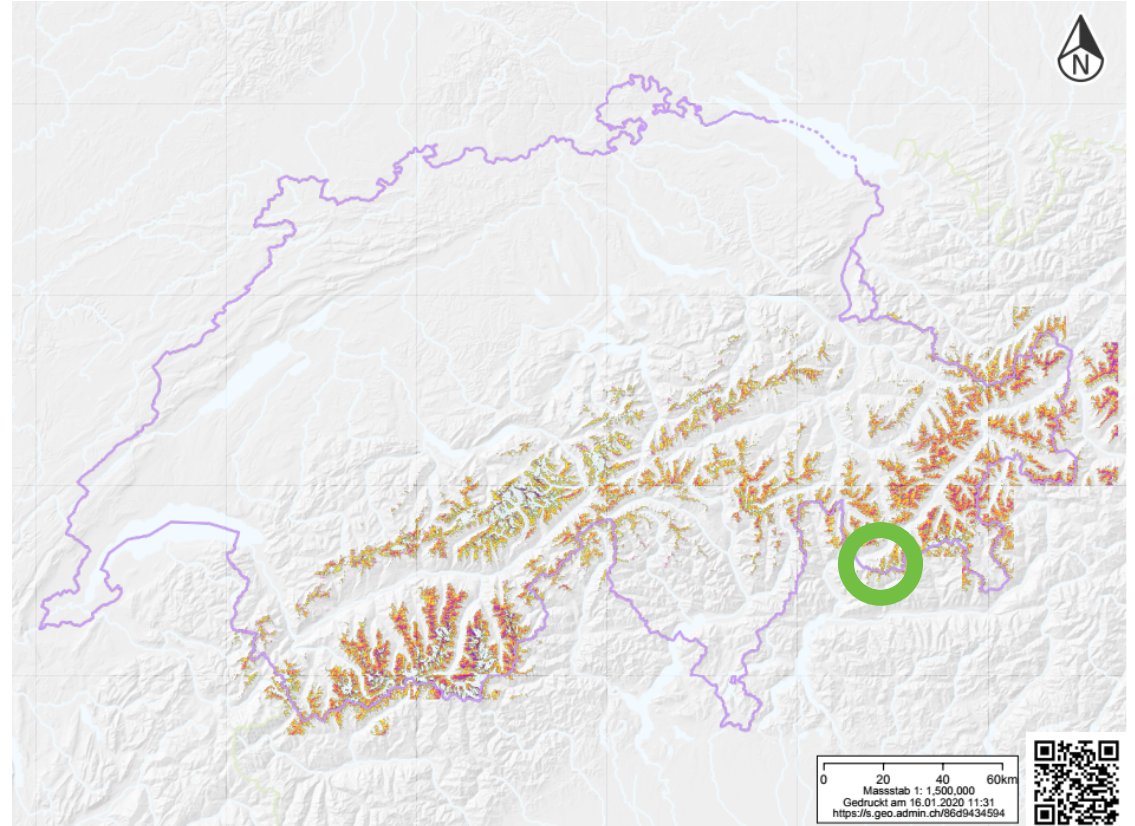
Permafrost: Frozen Ground



Increased Risk of Hazardous Rockfalls



Increased Risk of Hazardous Rockfalls



How to face the challenges of climate change?

How to face the challenges of climate change?

Find measures to mitigate the
impact of climate change

*How to prevent a
catastrophic rockfall?*

How to face the challenges of climate change?

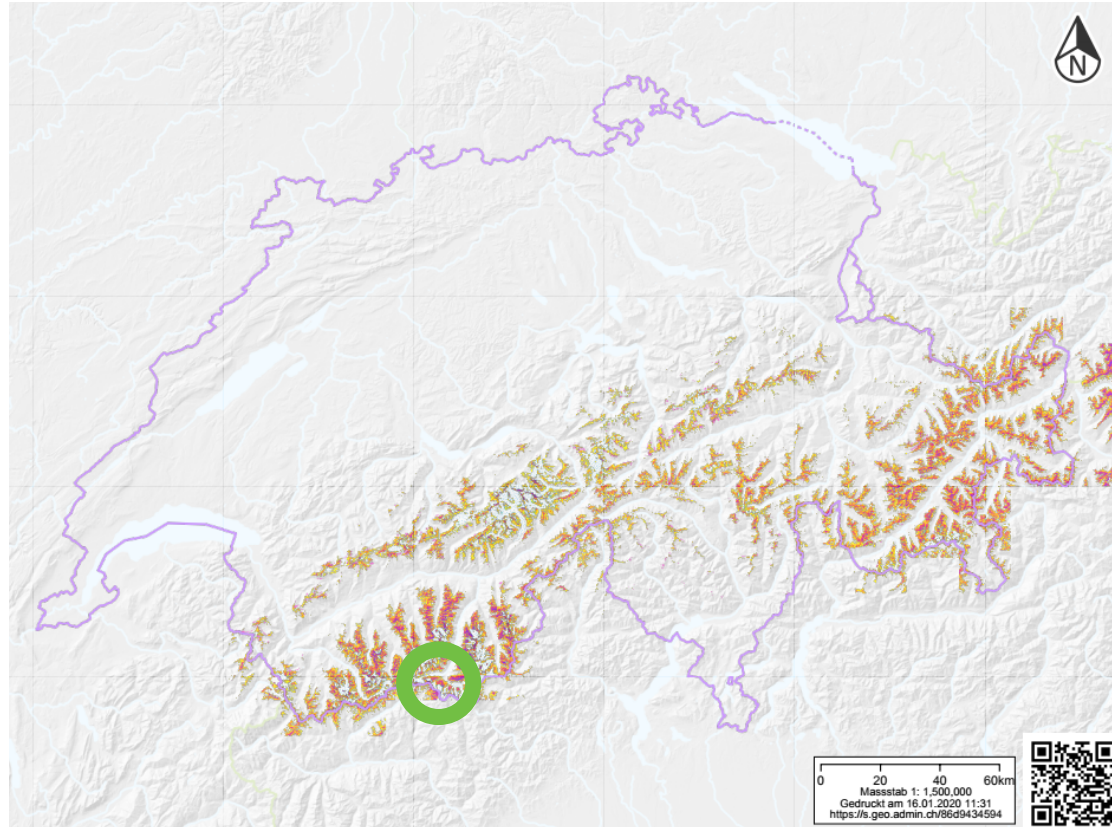
Find measures to mitigate the impact of climate change

How to prevent a catastrophic rockfall?

Understand processes of climate change

Which geophysical processes lead to a rockfall?

Monitoring Deployment in Canton of Valais (CH)



Monitoring Climate Change at the Edge of the Cloud



Monitoring Climate Change at the Edge of the Cloud



PermaSense: A Joint Effort

Jan Beutel, Samuel Weber, Reto Da Forno, Alain Geiger, Stephan Gruber, Tonio Gsell, Andreas Hasler, Matthias Keller, Roman Lim, Philippe Limpach, Matthias Meyer, Igor Talzi, Lothar Thiele, Christian Tschudin, Andreas Vieli, Daniel Vonder Mühl, Mustafa Yücel, and many more...



University of
Zurich ^{UZH}

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



How to face the challenges of climate change?

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Natural Hazard Warning

Understand processes of climate change

Which geophysical processes lead to a rockfall?

Fundamental Research

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Natural Hazard Warning

Edge Computing

Understand processes of climate change

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Fundamental Research

Cloud Computing

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Natural Hazard Warning

Edge Computing

Expert Knowledge

Understand processes of climate change

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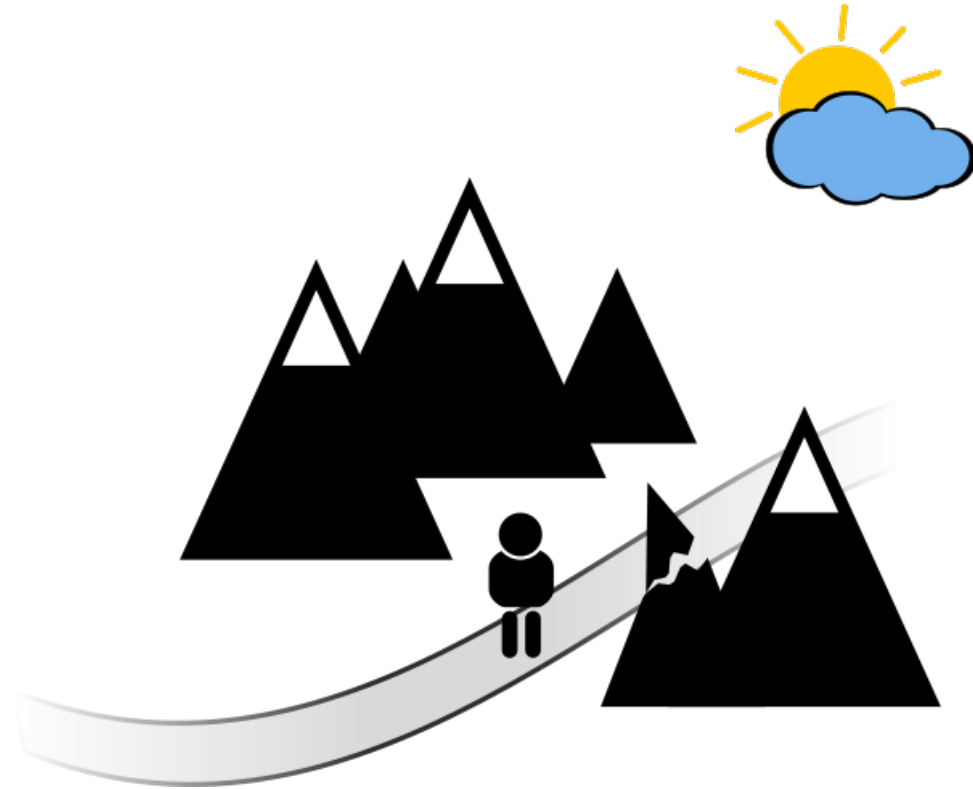
Fundamental Research

Cloud Computing

Machine Learning

Natural Hazard Warning

Fundamental Research



Objectives

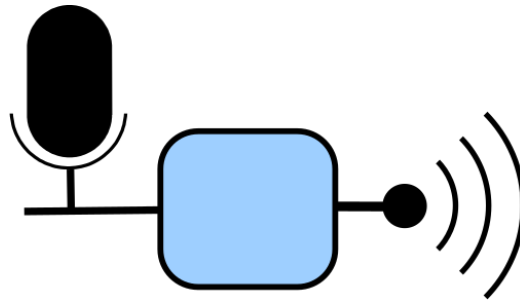
Natural Hazard Warning

- Fast reaction time
- Accurate during hazard
- High Reliability

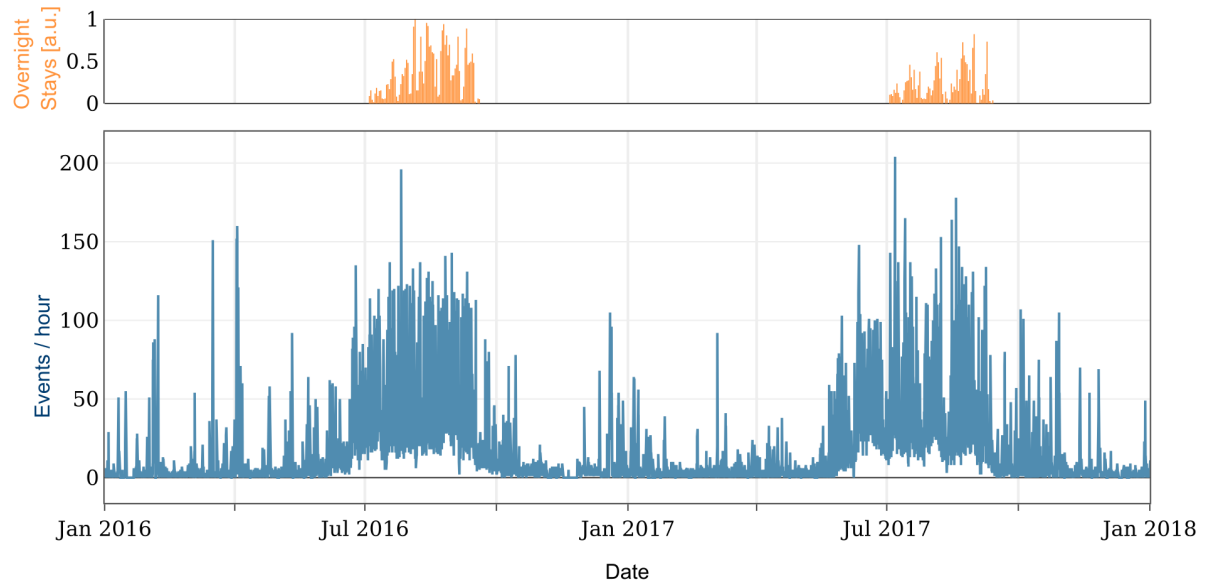
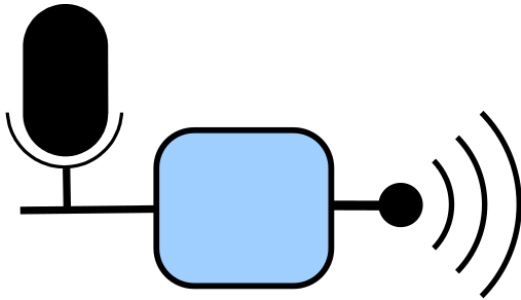
Fundamental Research

- Sound reasoning
- Long-term analysis
- Development of models

Geophones: Measuring Ground Vibrations



Measurements Distorted by External Influences



Use Cases of Mountaineer Classifier

Natural Hazard Warning

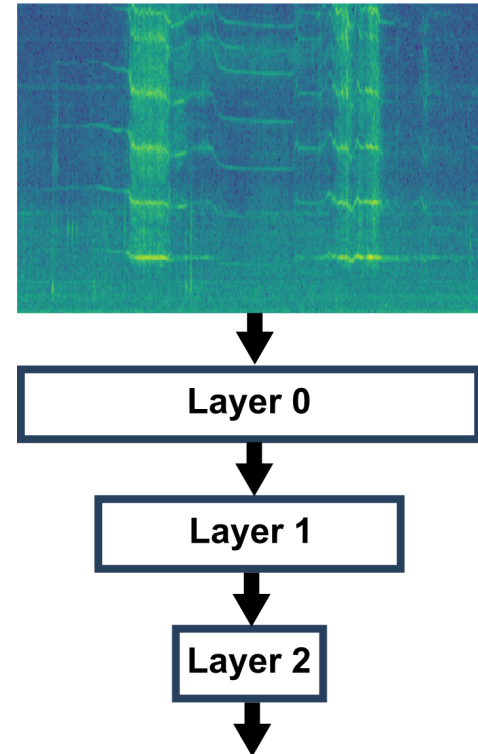
- Filter out mountaineers
- Detect if persons are in the danger zone
- Inform search and rescue mission in case of emergency

Fundamental Research

- Filter out mountaineers
- Quantifying the number of persons in nature conservation areas

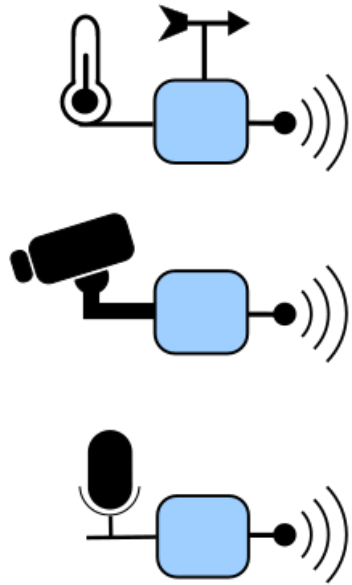
Mountaineer Classifier

- Manually labelled images and seismic data
- Based on Fully Convolutional Neural Network
- Error Rate < 1%
- F1 Score 0.94

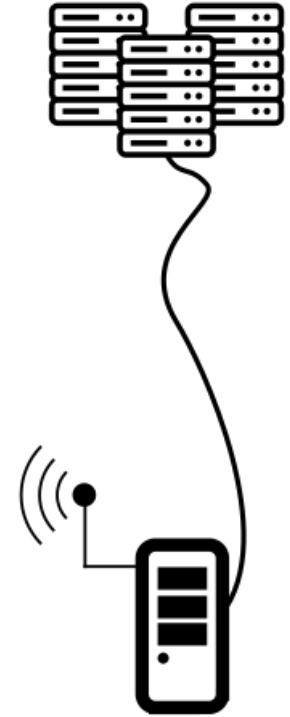


**How to compute the
classifier in deployment?**

Edge Computing



Cloud Computing



Trade-offs

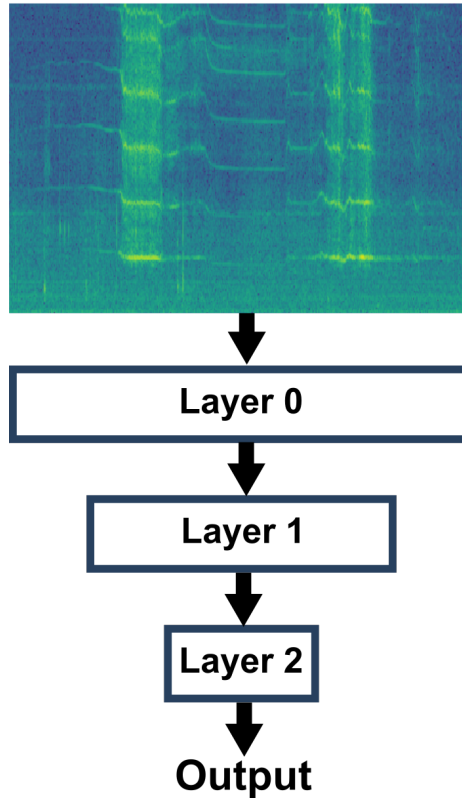
Edge Computing

- Fast response time
- Limited by the availability of energy, processing power and memory

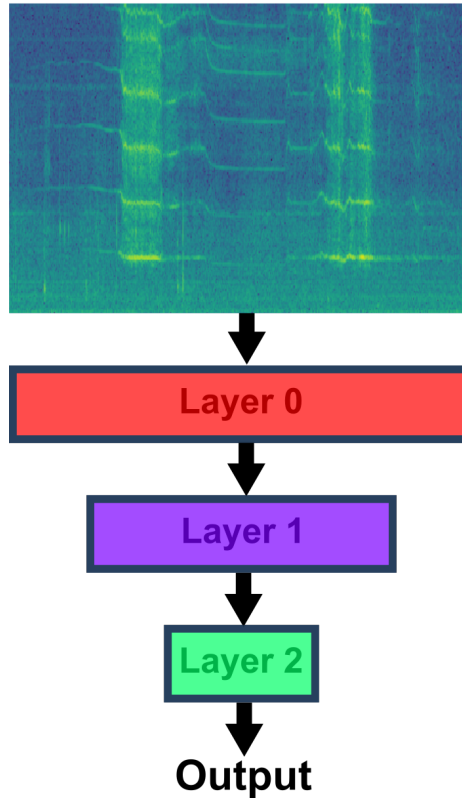
Cloud Computing

- Additional delay
- "Unlimited" resources

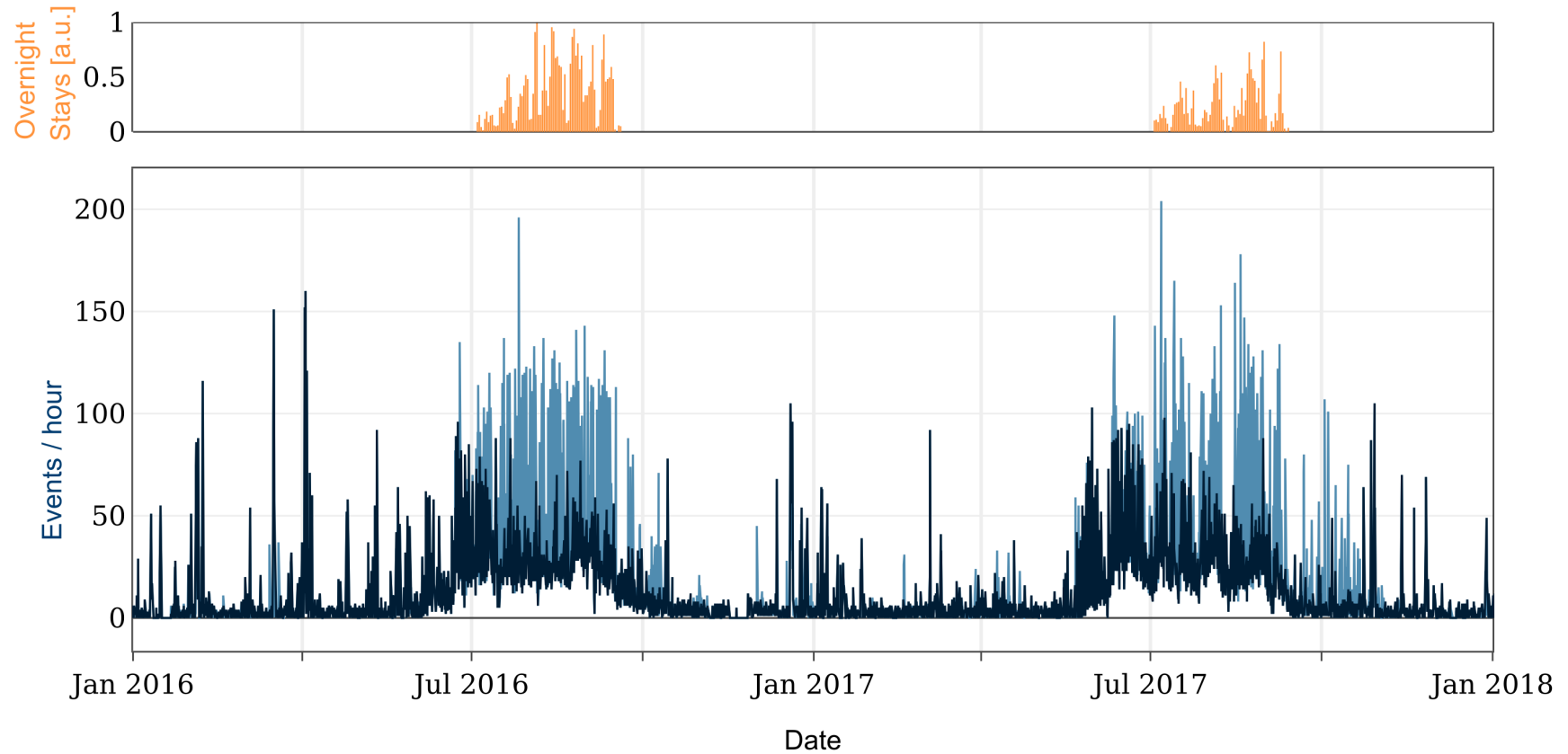
Mountaineer Classifier in the Cloud



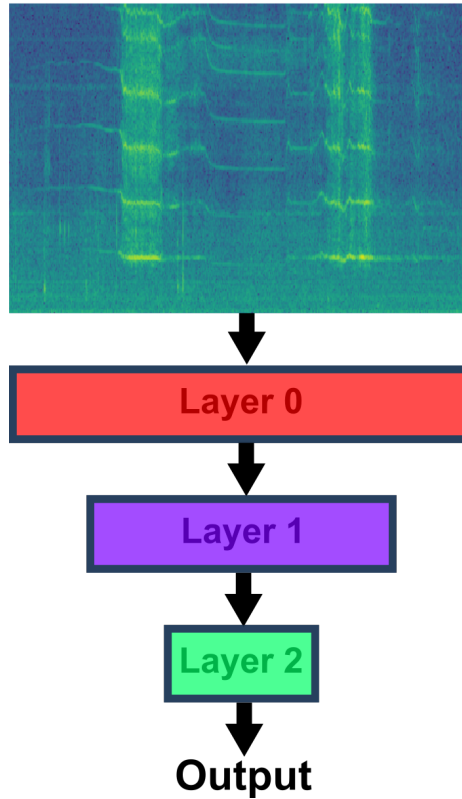
Mountaineer Classifier in the Cloud



Mountaineer Classifier in the Cloud

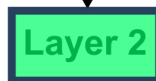
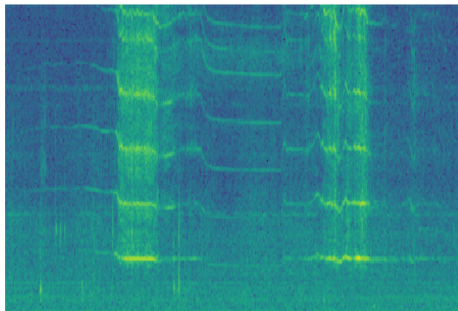


Can we use the same model on the edge?



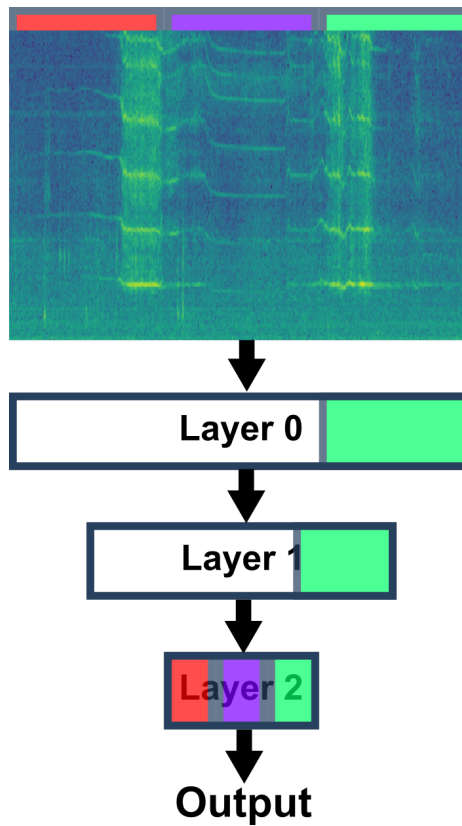
Can we use the same model on the edge?

Memory Bottleneck

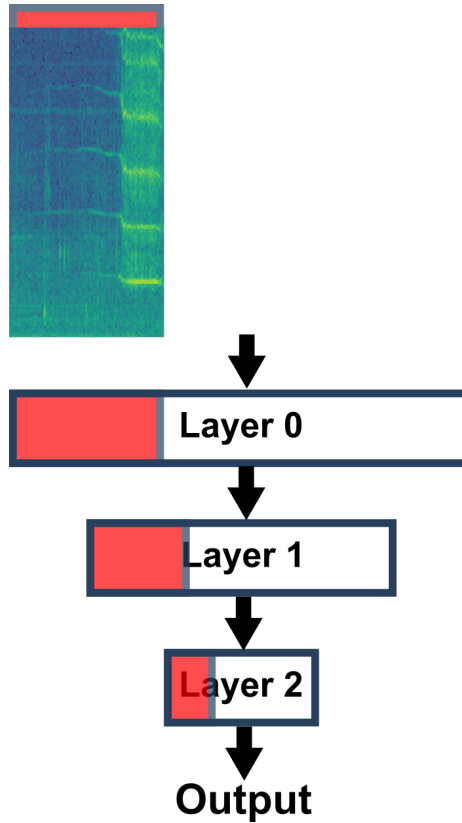


Output

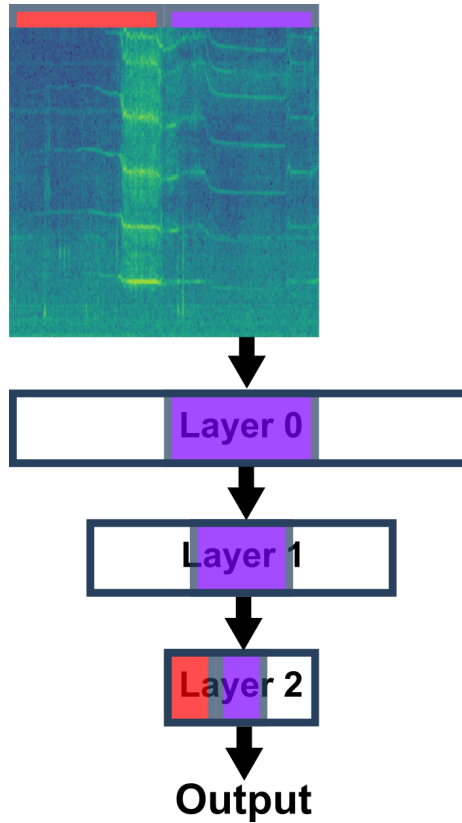
Receptive Field



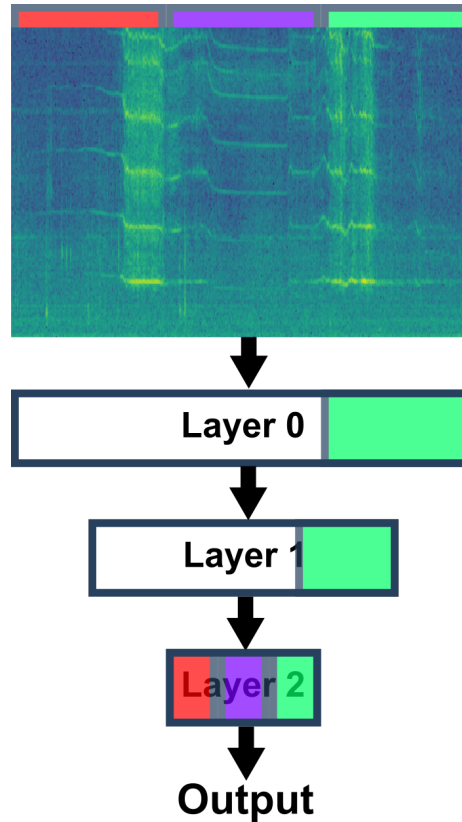
Time Distributed Processing



Time Distributed Processing



Time Distributed Processing on the Edge



**Approach enables CNN
on resource-limited
devices**

Implementation

Edge Computing

- Time distributed processing for custom-made geophone
- Prototype of natural hazard warning system

Cloud computing

- Training of mountaineer classifier
- Filtering of mountaineers to improve long-term analysis

Implementation

Edge Computing

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OPEN SOURCE

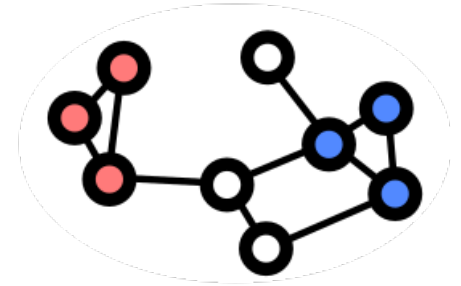
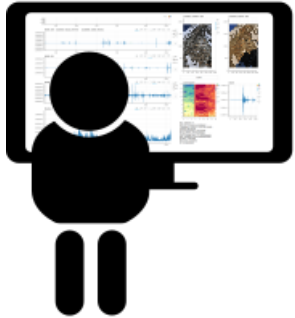
M. Meyer et al., "Event-triggered Natural Hazard Monitoring with Convolutional Neural Networks on the Edge," in Proceedings of the 18th IPSN Conference, 2019

M. Meyer et al., "Systematic identification of external influences in multi-year microseismic recordings using convolutional neural networks," *Earth Surface Dynamics*, 2019,

DECISION MAKING

Expert Knowledge

Machine Learning



Trade-offs

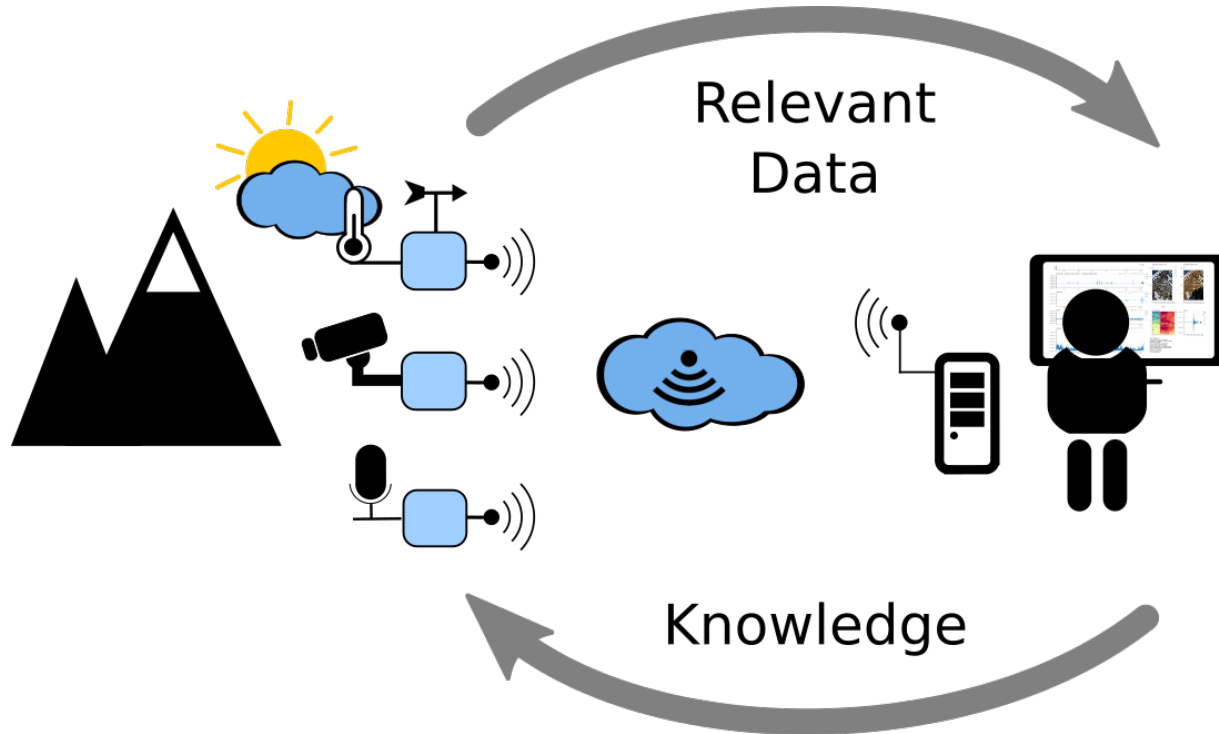
Expert Knowledge

- Comprehensible
- Not scalable

Machine Learning

- Black box
- Scalable

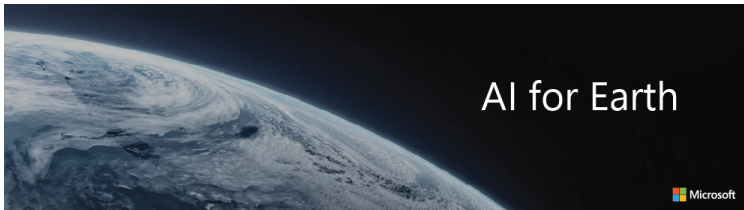
Knowledge Feedback Loop



Multi-View Data Exploration

Expert Knowledge

- Interactive online analysis tool
- Working with domain experts
- Hackathon on Permafrost 2019



Machine Learning

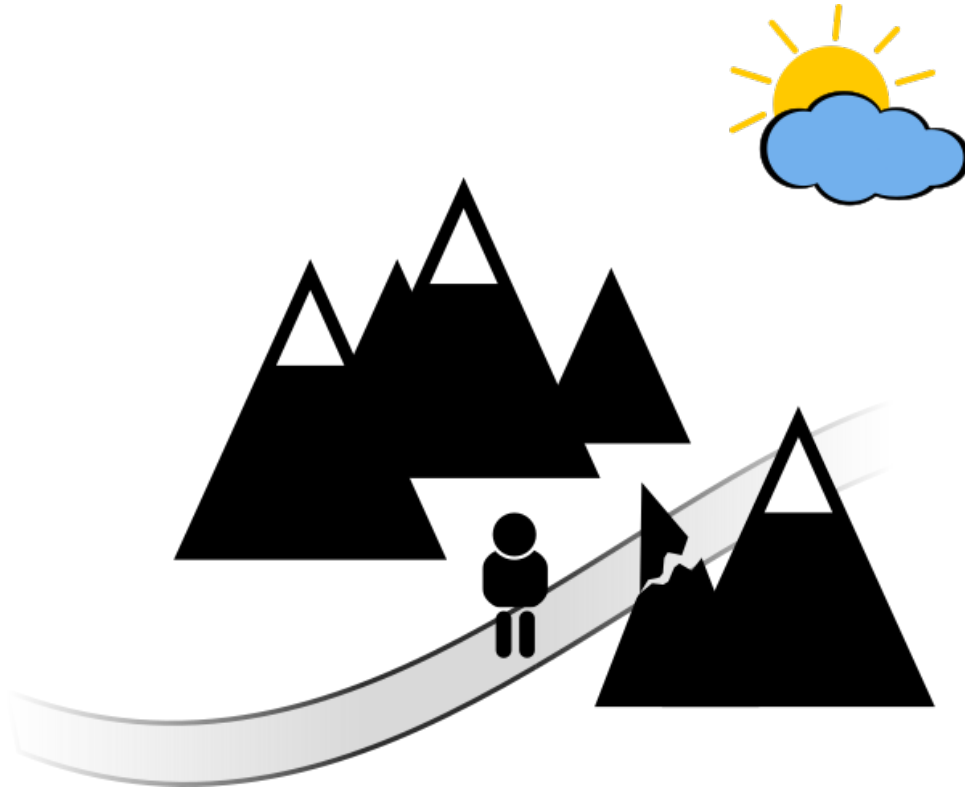
- Unsupervised learning
- Topological embedding
- Mutual information maximization



SUMMARY

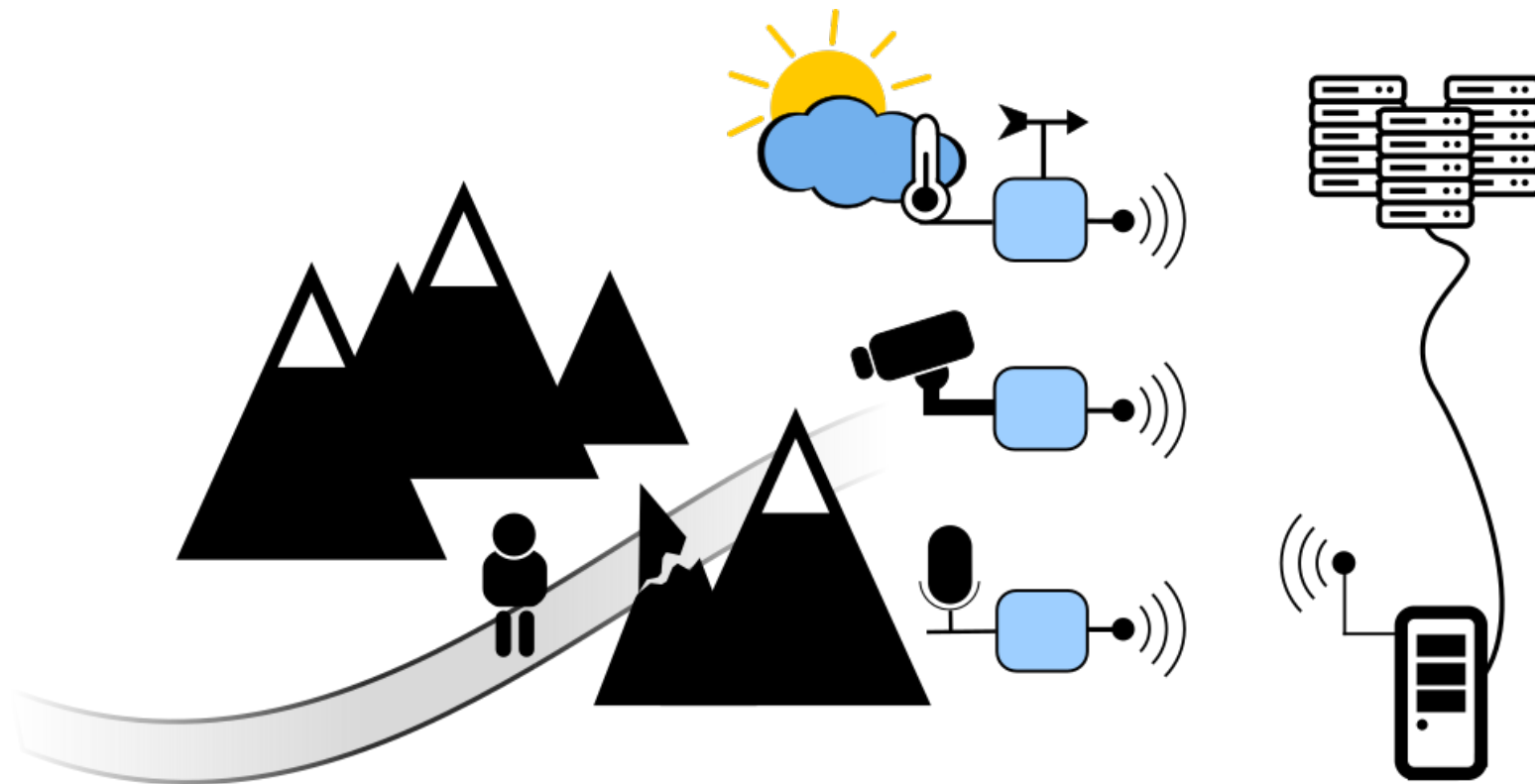
Natural Hazard Warning

Fundamental Research



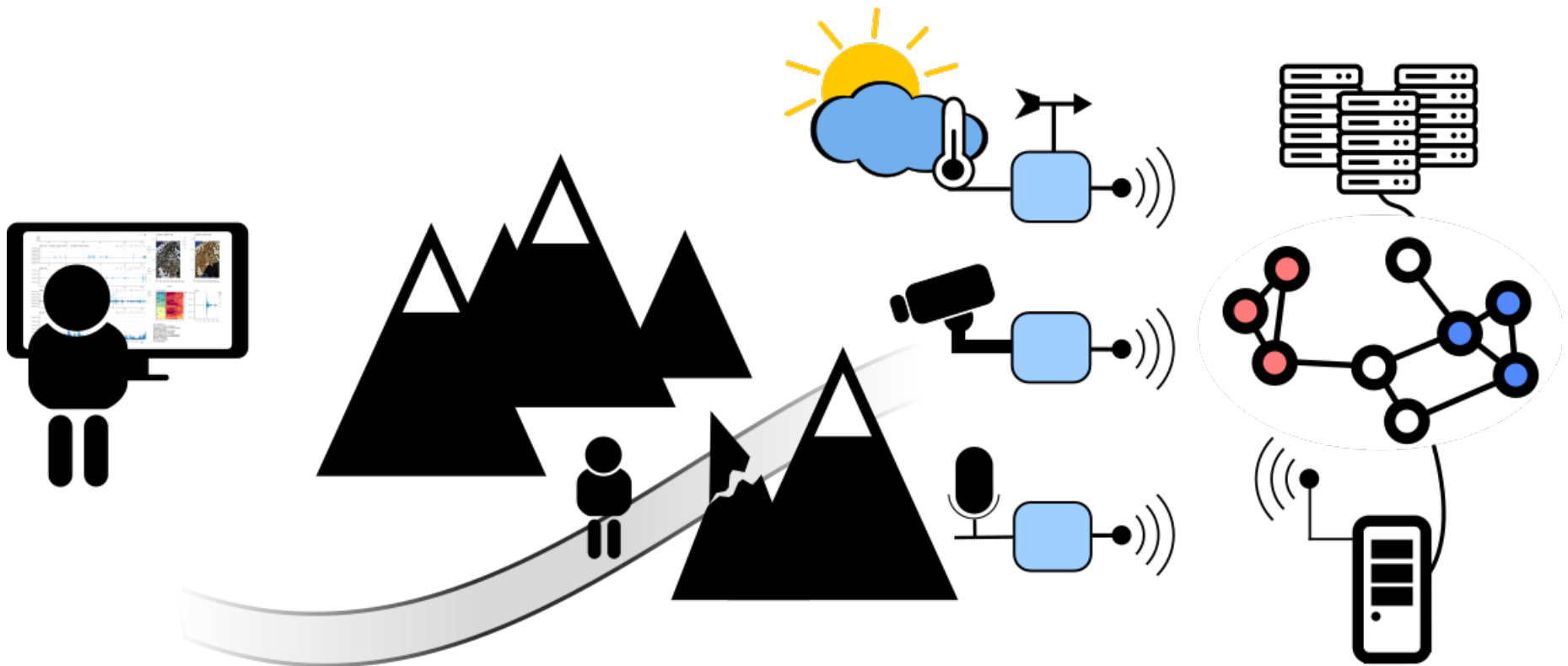
Edge Computing

Cloud Computing

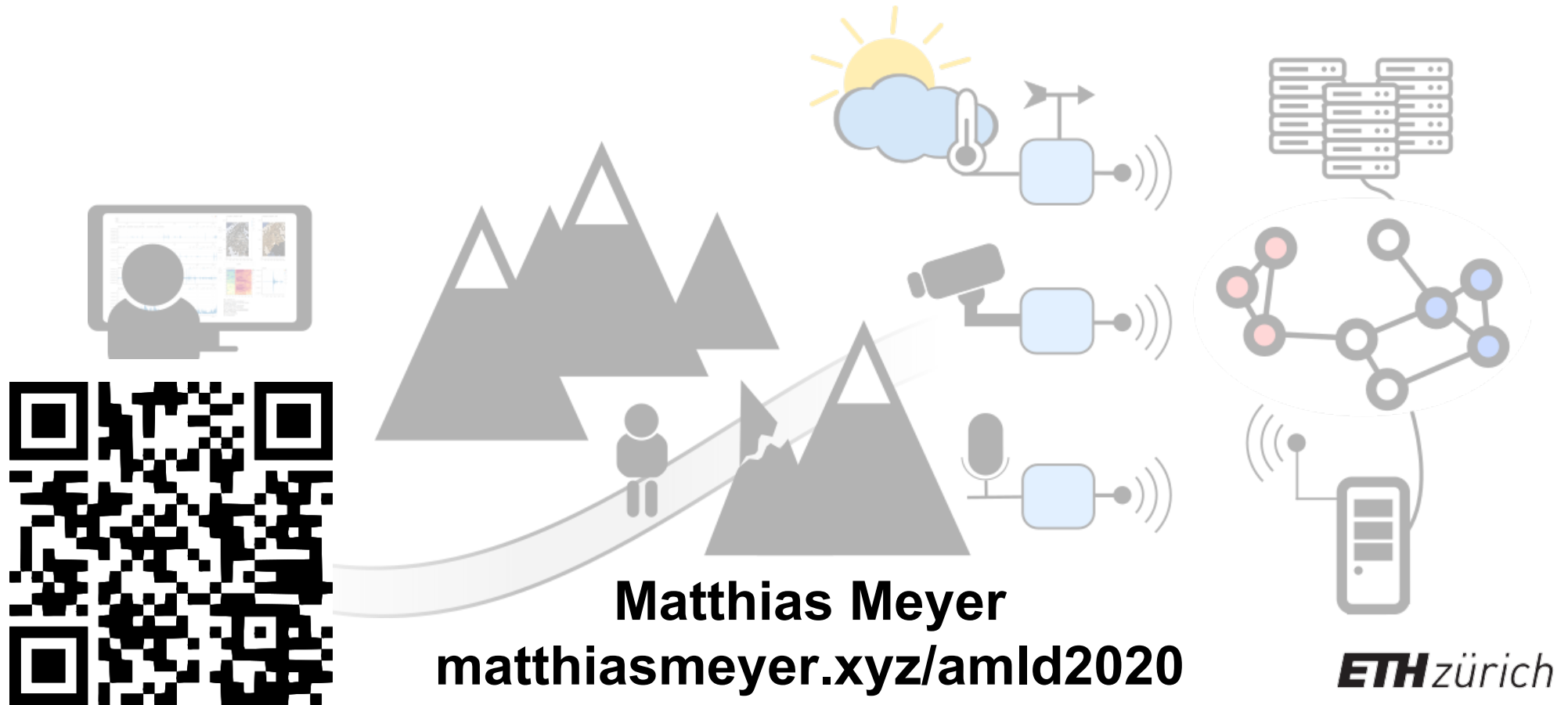


Expert Knowledge

Machine Learning



Monitoring Climate Change at the Edge of the Cloud



List of Media

- Banner Cloud formation on the Matterhorn by simonsimages
<https://www.flickr.com/photos/20722833@N00/3777855034>
- "Ilulissat Icefjord, Greenland" by Stian Klo is licensed under CC BY-NC-ND 4.0
<https://ccsearch.creativecommons.org/photos/db0a3587-17e1-4b9b-a176-72255507a12a>
- Permafrost map of Switzerland by BAFU / EUA, BAFU, swisstopo, map.slf.ch
<https://s.geo.admin.ch/86d9434594>
- Youtube, <https://www.youtube.com/watch?v=AN-WVBtXtlk>

View

