Deliverable

[D2.1 – Large-scale DAS logistic feasibility study on new applications]

Deliverable information	
Work package	[WP2]
Lead	[ETH]
Authors	[Andreas Fichtner, Krystyna Smolinski and Sara Klaasen, ETH Zurich]
Reviewers	[Ian Main as WP2 Leader]
Approval	[Management Board]
Status	[Final]
Dissemination level	[Public]
Will the data supporting this document be made open access? (Y/N)	[Yes]
If No Open Access, provide reasons	
Delivery deadline	[31.08.2021]
Submission date	[24.08.2021]
Intranet path	[DOCUMENTS/DELIVERABLES/File Name]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821115

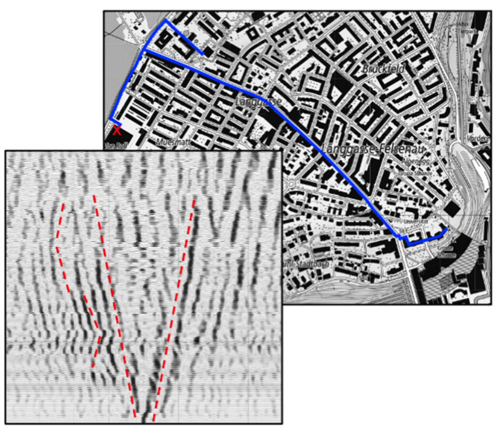
Table of contents

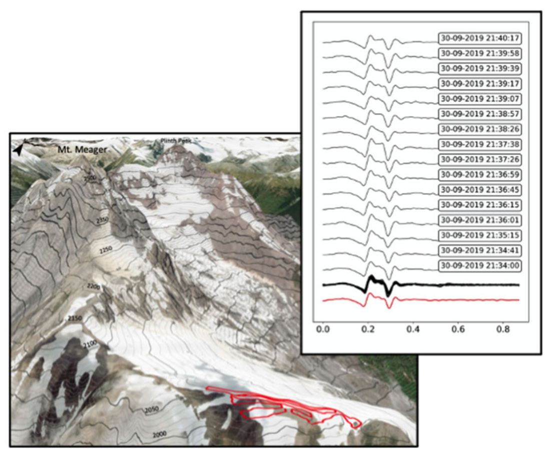
Summary

This report summarises a series of Distributed Acoustic Sensing (DAS) experiments, aiming to establish the logistic feasibility and scientific value of this emerging technology. While one experiment was conducted in an urban environment, two others took place on (partly) glacier-covered active volcanoes. In all cases, it was possible to setup the experiment with reasonable effort, whereas the deployment of a comparable number of conventional sensors with similar bandwidth would have been logistically and financially impossible. The urban experiment shows that DAS is able to constrain subsurface structure at spatial scales down to a few metres, using both anthropogenic noise and active (hammer blow) data. Both experiments on volcanoes detected a previously unknown level of seismicity, including long-lasting volcanic tremor.

1. Introduction and outline

Within this task, we investigate the use of emerging Distributed Acoustic Sensing (DAS) technologies from several perspectives: (1) the logistics of using DAS in urban environments and in terrain where dense networks of conventional seismic sensors cannot be installed easily, (2) the possibility to detect and characterize a broader spectrum of seismic events than with existing seismic networks, and (3) the feasibility of local tomography studies using DAS recordings of ambient noise or deterministic events. In addition to several small experiments, we conducted three major ones. These are summarized in the figure below and detailed in the following chapters.





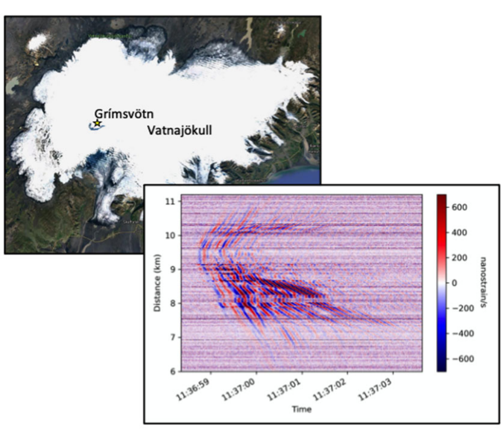


***Figure**: T<u>op left</u>: Telecom cable layout used for a DAS experiment in Bern (upper right). Anthropogenic noise correlations (lower left) can be used to constrain structure at 10 m scale. <u>Top right</u>: Deployment of a DAS cable on a ridge of Mount Meager, and active volcano in British Columbia (left). The DAS array recorded a previously unknown level of seismic activity, including numerous repeating events (right). <u>Bottom left</u>: In April 2021, we deployed a 12 km long cable around Grimsvötn, Iceland's most active volcano (upper left). The DAS array records numerous low-magnitude volcanic earthquakes that are not seen on the regional seismic network stations.*

2. Urban DAS fully operational

In collaboration with colleagues from the SWITCH Foundation, we performed an urban DAS experiment in the Swiss capital of Bern. The experiment was intended to serve several purposes: (1) assess the logistic feasibility of such an experiment, (2) analyse data quality and characterize the recorded signals, and (3) infer local subsurface structure that may be useful for site characterization and hazard assessment.

The installation of the DAS interrogator in a server room of the University of Bern was surprisingly simple and accomplished within few hours. We connected a Silixa iDAS to a 6 km long fibre, originally intended for telecommunication. We recorded data for a duration of 2.5 weeks, using a channel spacing of around 2 m and a sampling rate of 200 Hz. This resulted in a data volume of approximately 1.5 TB.

Though the cable was obviously installed for different purposes and not specially coupled to the ground, data quality is generally remarkable. Road traffic is visible with the naked eye. Both the speed of the traffic and the propagation velocity of the excited surface waves can be estimated already from the raw data, without the need for any sophisticated method. Jumps on the pavement also produced very clear and reproducible signals, which we used not only to locate channels but also to infer local structure to several tens of metres of depth. Anthropogenic noise correlations also produce clear surface wave signals. The correlations appear more complex than regional-scale ambient noise correlations, most likely due to the presence of reflections off the basements of buildings. A tomographic inversion of the noise correlations is work in progress.

3. The Mt. Meager experiment

On Mt. Meager in British Columbia, we performed the first DAS experiment on a glacier-clad active volcano, together with colleagues from the University of Calgary. In total, we deployed around 3 km of fibre-optic cable on a ridge, near the summit of Mt. Meager, which is Canada's most active volcano, with high geothermal potential. Around 2 km of the cable were trenched into the glacier that partly covers the northern flank of Mt. Meager. The experiment ran for around 1 month.

The data reveal a previously unknown level of seismicity, including high-frequency events that form distinct clusters and long-period tremor. In addition to painting an entirely new picture of Mt. Meager's activity, this experiment also demonstrates that DAS experiments are logistically possible in harsh terrain where the installation of traditional seismometer arrays with similar coverage in space and frequency would be close to impossible.

4. The Grimsvötn experiment

Encouraged by the results from Mt. Meager, we performed the so far largest DAS experiment on an active volcano, Grimsvötn, in Iceland. Almost completely covered by the Vatnajökull ice cap, Grimsvötn is the most active volcano of Iceland, on a decadal time scale. Using a specially designed sled, we trenched more than 12 km of cable in the ice, half way around and into the caldera.

Similar to Mt. Meager, the data reveal the presence of an unexpectedly high seismicity, with numerous small events that have not been detected by the regional seismometer network. The

seismicity also includes previously unknown tremor that appears particularly pronounced right above the caldera.
The Grimsvötn experiment perfectly exemplifies the logistic feasibility of large-scale DAS experiments in environments where comparable arrays of conventional seismometers are impossible to install, also for financial reasons. In both the Mt. Meager and the Grimsvötn experiments, the effective cost per channel (including cable and deployment costs) is around 10 Euros. Keeping in mind that the bandwidth of our iDAS ranges from mHz to kHz, comparable broadband sensors would be orders of magnitude more expensive.