Karlsruhe Institute of Technology

Geophysical Institute, KIT-Department of Physics
Hertzstr. 16, 76187 Karlsruhe
www.gpi.kit.edu/index.php

Contact for alumni affairs: Kerstin.Dick@kit.edu

NEWSLETTER OF THE GEOPHYSICAL INSTITUTE

DEAR GPI ALUMNI

The first half of 2018 has passed by rather quickly with a lot of new activities starting from which I can only list a few. GPI is participating in two newly funded EU projects, NARSIS (New Approach to Reactor Safety ImprovementS) and DARE (Delivering Agile Research Excellence on European e-Infrastructure). Research and teaching links with the Institut Teknologi Bandung (ITB), Indonesia, have been reignited with a joint Summer School on Seismology and Geohazards. GPI is also branching out into medical sciences by applying geophysical techniques like Full Waveform Inversion (FWI) and Reverse Time Migration (RTM) in the field of mammography. We are reinstating real-time data transmission on our local seismic network and, jointly with the University of Liverpool, have established a real-time monitoring network at Santiaguito volcano, Guatemala, that is currently being extended to also cover the recently erupting Fuego volcano. Much closer to home refurbishing of 6.42 is nearly finished, which will provide better facilities to all our staff and visitors. I would like to take the opportunity to thank everybody for their hard work and I am looking forward to an exciting and stimulating 2nd half of 2018. I wish everybody a well-earned summer break.

Andreas Rietbrock

SEISMOLOGICAL AND INFRASOUND MEASUREMENTS AT SANTIAGUITO VOLCANO, GUATEMALA

By Ellen Gottschämmer, Amelie Nüsse and Andreas Rietbrock

The Karlsruhe Institute of Technology (KIT) and the University of Liverpool (ULIV) have set up a network of four seismic stations and three infrasound stations at Santiaguito volcano, Guatemala, in 2018.

Santiaguito has been continuously active since 1922 when it formed as a complex of dome extrusions within the collapse scar of the Santa Maria 1902 eruption. Presently, activity is concentrated at the eastern vent, named Caliente. Within the last few years, gas- and ash explosions at Santiaguito volcano occurred regularly at intervals between 20 and 200 minutes. In January 2018, we deployed the stations which are located at distances between 2.2 and 7.6 km from the active vent. They are either set up in plastic barrels with concrete foundation buried in the ground or on concrete splints within so called ‘casitas’, small huts for the safe deployment of scientific equipment (Figure 1).

Figure 1: Top row from left: Santiaguito volcano with Santa Maria volcano in the background, hut for station deployment at station Loma Linda, setup of solar panels at station VIP camp. Bottom row: installation of seismic station within plastic barrel at station New OVSAN. Photo: Andreas Rietbrock

Seismic sensors used are Trillium compact 120s seismometers as well as Lennartz 1s seismometers and infrasound sensors are of type prs100. Power is supplied by solar panels charging car batteries. The data is digitized by Earth Data EDR209 dataloggers continuously recording at 100 Hz (32bits resolution).

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The seismic data from three of the stations is received in real-time, via modem streaming, at INSIVUMEH (Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hydrologia) in Guatemala City (Figure 2). Data is then transmitted to KIT instantaneously and analyzed by KIT seismologists. Thus, during the last six months we have collected 30 GB of seismic data and 10 GB of infrasound data. In May 2018, we revisited the stations, exchanged and improved some of the installations and collected the infrasound data and seismic data from one of the stations which had not been transmitted to KIT yet.

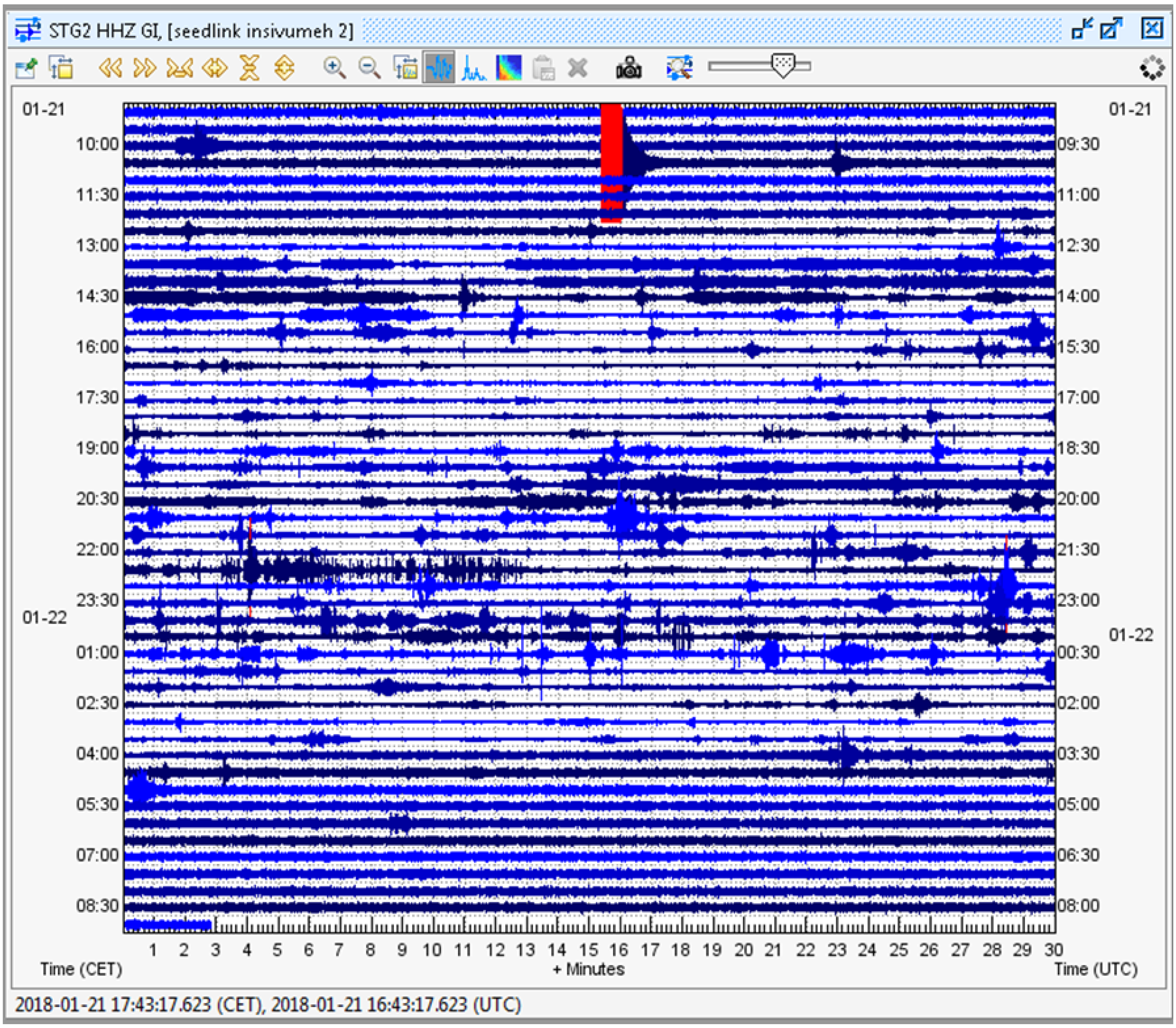


Figure 2: Data stream from station Loma Linda, vertical component (21 -22 January 2018).

We developed an automatic detection algorithm for volcanic explosions and earthquakes and applied it to the data. Around 1090 volcanic explosions and 1740 regional and local earthquakes could be observed (Figure 3).

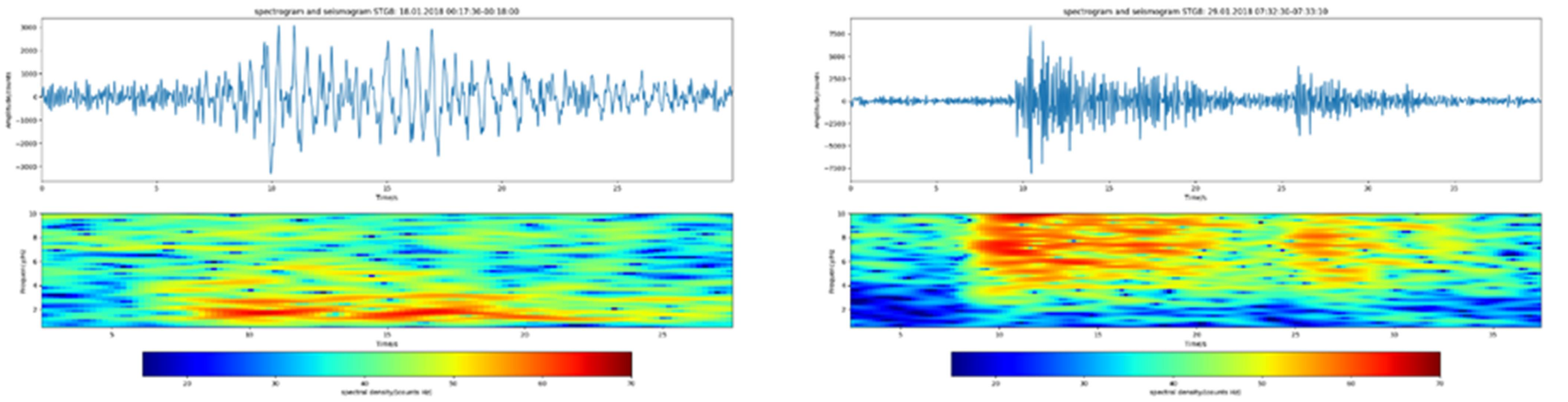


Figure 3: Left: Explosion recorded at station VIP Camp, vertical component, 18 January 2018. The top trace shows the time series. The bottom image shows the spectrogram showing clearly that the explosion signal is dominated by frequencies around 2 Hz. Right: Earthquake recorded at VIP Camp, vertical component, 29 January 2018. The top trace shows the time series. The bottom image shows the spectrogram showing clearly that the earthquake signal is dominated by frequencies around 6 Hz.

The algorithm computes Fourier spectra for time series of 2 minutes. Earthquake spectra computed from the data at Santiaguito usually contain frequencies between 5 and 9 Hz, while spectra from volcanic explosions have dominant frequencies around 1 to 3 Hz. To classify an event, its Fourier spectrum is compared to the estimated mean spectra of both event types.

Furthermore, an automatic detection algorithm for harmonic tremor has been developed at KIT. We found several harmonic tremor episodes per day that lasted up to several minutes, comprised 10 or more overtones and were often accompanied or preceded by volcanic explosions (Figure 4).

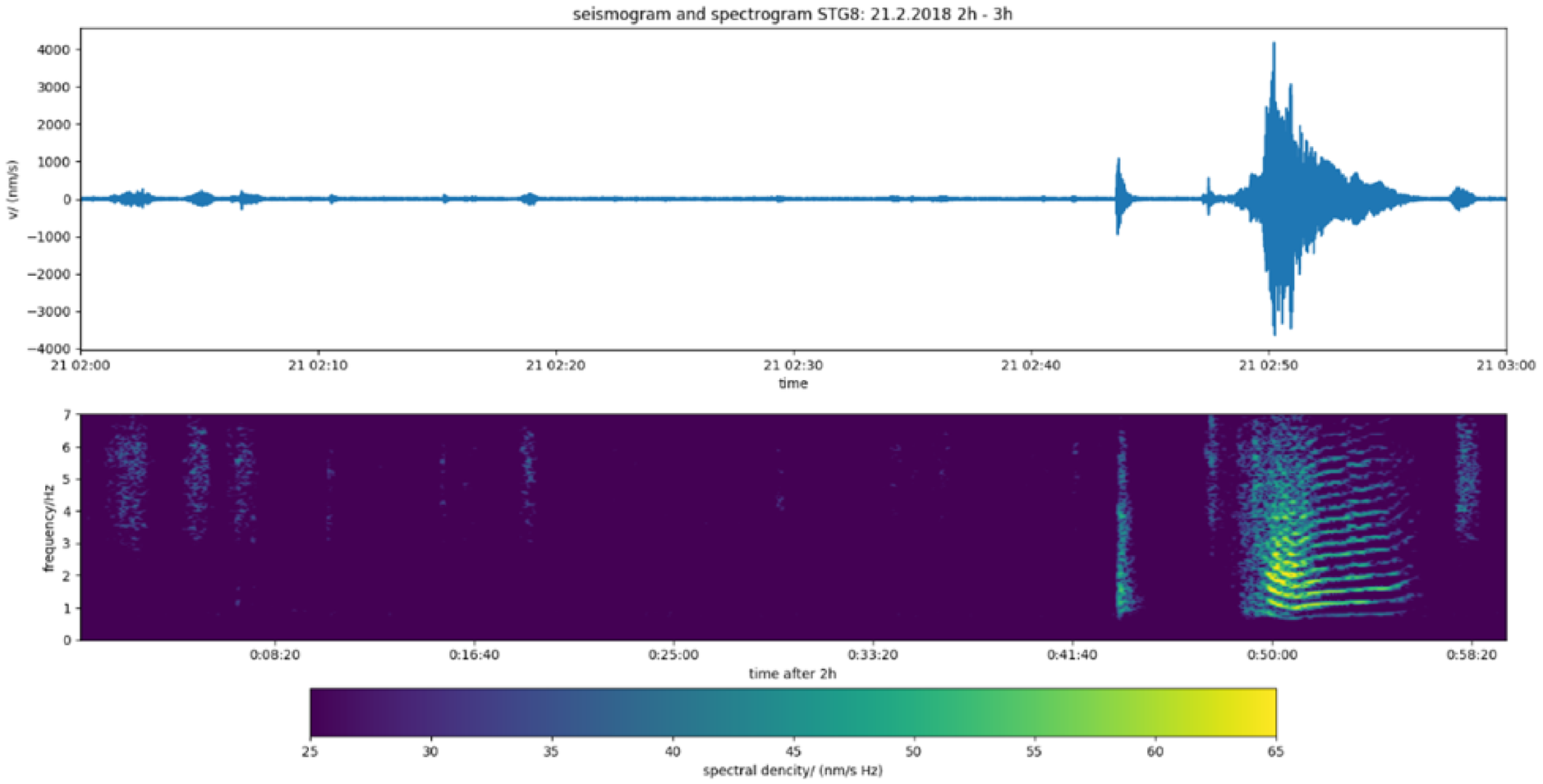


Figure 4: Seismogram and spectrogram computed for station VIP Camp, vertical component, 21 February 2018. An explosion can be seen at 2:42 UTC and harmonic tremor starts at 2:49 UTC.

ULTRASOUND MEDICAL IMAGING USING FULL - WAVEFORM INVERSAION

By Fabian Kühn, Nico Heinz, Thomas Hertweck and Thomas Bohlen

Mammography using x-rays is the standard approach for breast-cancer screening. However, nowadays it is more and more often replaced by ultrasound methods that are non-invasive and, in addition, provide more reproducible results because a woman's breast is not deformed during data acquisition.

In a new project at the Geophysical Institute in cooperation with KIT-IPE, we would like to investigate the benefit of transferring the well-known full-waveform inversion (FWI) and reverse-time migration (RTM) approaches to medical imaging. Current state of the art in ultrasound breast-cancer screening is the use of travel time tomography and a simplified form of Kirchhoff migration to create ultrasound images of a woman's breast.

By exploiting more information of the measured waveform, we expect to exceed the resolution limits of kinematic, ray-based methods although at the expense of much higher computational costs.

First reconstruction tests with a numerical, anatomically realistic breast model were successful. The resolution could be significantly improved and an almost perfect match of waveforms for the true and reconstructed model was obtained. Next, we will use 2D FWI and RTM to image single cross-sections with fully 3D acquired clinical data provided by KIT-IPE. Currently, the challenges associated with such data (e.g., movement of the breast during data acquisition, noise issues, etc.) are investigated. The final, long-term goal is optimizing the reconstruction algorithms to enable the detailed analysis of clinical data using visco-acoustic FWI and RTM.

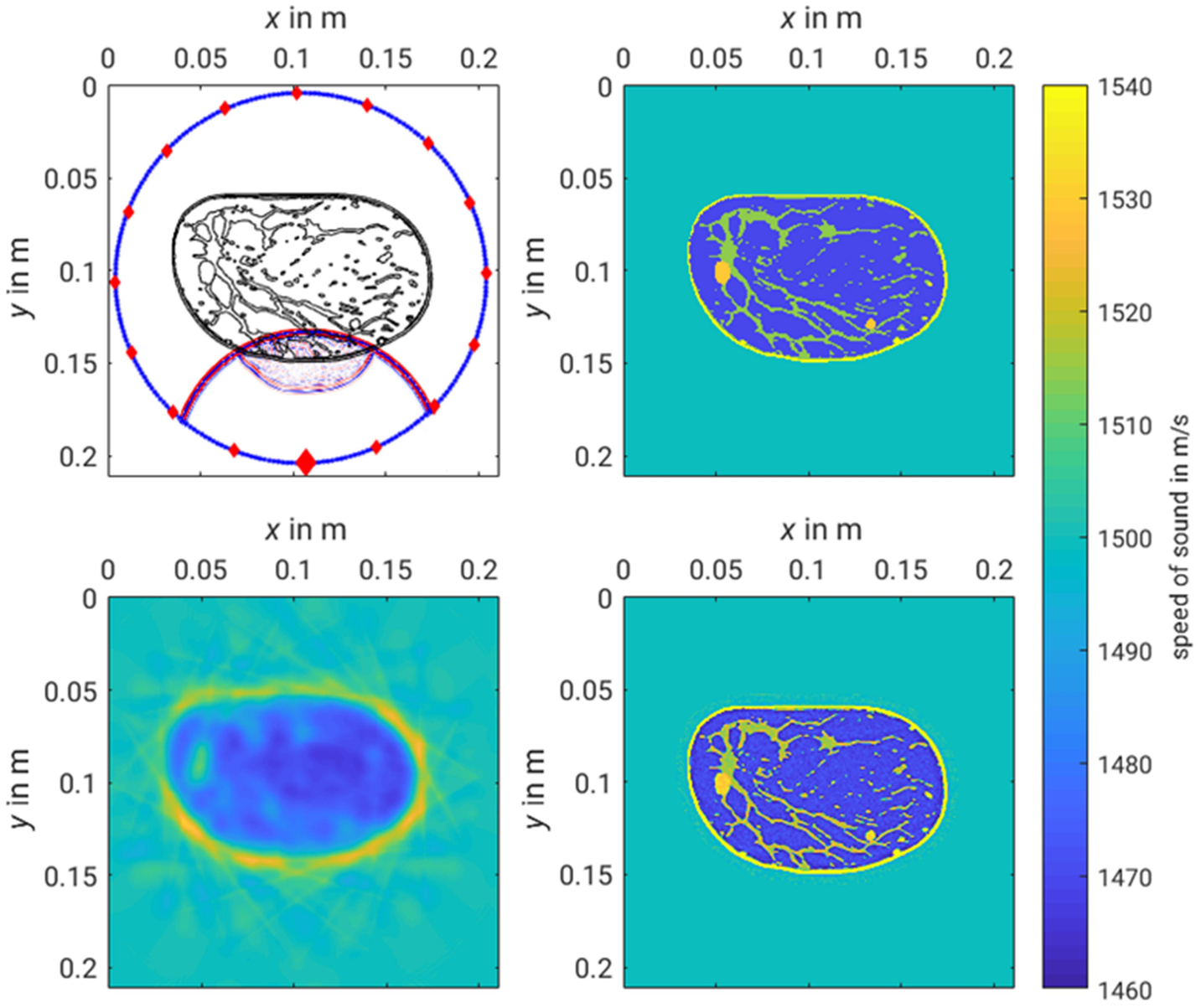


Figure 1. Top left: source-receiver geometry (16 sources shown as red diamonds, 256 receivers are distributed along the transducer ring shown in blue) including a wavefield snapshot at t = 50 microseconds for the highlighted source position at the bottom; the diameter of the transducer ring is 20 cm. top right: anatomically realistic breast model after Y. Lou (2017); bottom left: velocity model obtained by means of ray-based tomography (courtesy of KIT-IPE); bottom right: velocity model obtained by mean

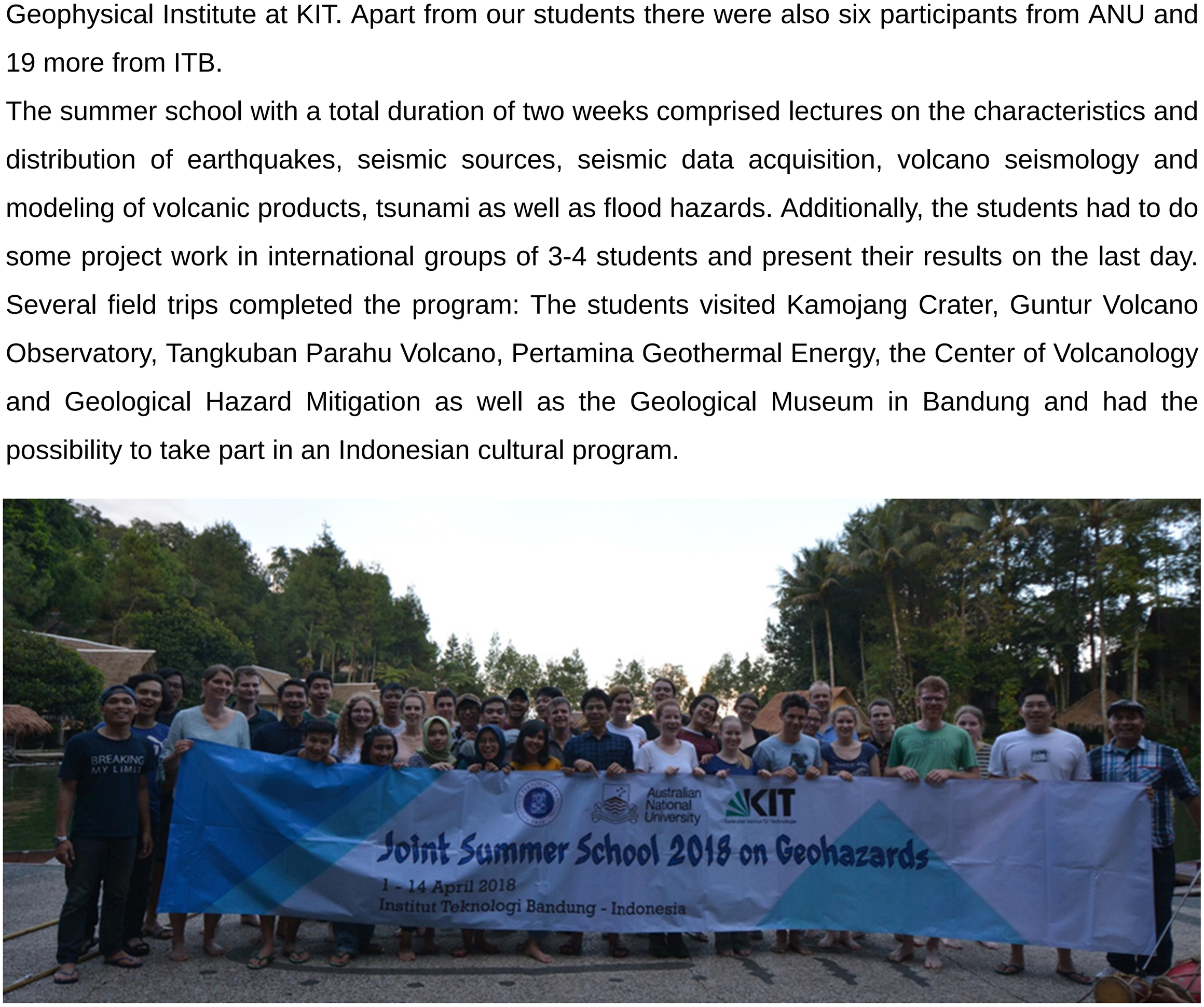
1 For additional information about ultrasound medical imaging at KIT-IPE, please visit https://www.ipe.kit.edu/167.php

SUMMER SCHOOL ON SEISMOLOGY AND GEOHAZARDS, APRIL 2018, BANDUNG, INDONESIA

By Ellen Gottschämmer

Ten students from KIT took part in a Summer School on Seismology and Geohazards, jointly organized by the Institut Teknologi Bandung (ITB), Australia National University (ANU) and the Geophysical Institute at KIT. Apart from our students there were also six participants from ANU and 19 more from ITB.

The summer school with a total duration of two weeks comprised lectures on the characteristics and distribution of earthquakes, seismic sources, seismic data acquisition, volcano seismology and modeling of volcanic products, tsunami as well as flood hazards. Additionally, the students had to do some project work in international groups of 3-4 students and present their results on the last day. Several field trips completed the program: The students visited Kamojang Crater, Guntur Volcano Observatory, Tangkuban Parahu Volcano, Pertamina Geothermal Energy, the Center of Volcanology and Geological Hazard Mitigation as well as the Geological Museum in Bandung and had the possibility to take part in an Indonesian cultural program.



Participants in the Joint Summer School in April 2018 during a field trip at Kampung Sampireun
Photo: Riskiray Ryannugroho

We plan to continue this successful cooperation in teaching with ITB and ANU not only to learn from each other and profit from different scientific backgrounds but also to give our students the opportunity to work and study in an international group of students and thus broaden their personal horizons.

Students working on their project in the lecture hall at ITB
Photo: Riskiray Ryannugroho

PhD at GPI

Mr. Andreas Schäfer

In May 2018 Dipl.-Ing. M.Sc. Andreas Schäfer successfully defended his PhD thesis.

Title: Development of a Global Tsunami Risk Model
Supervisors:
Prof. Dr. Friedemann Wenzel (KIT)
Prof. Dr. Vincent Heuveline (University of Heidelberg)

The goal of his research was to develop a globally uniform and robust tsunami risk assessment framework. This methodology is the first one ever developed with a global focus since only a small number and very regional studies for tsunami risk have been published so far. The system was developed on the findings of the 2004 Sumatra, 2011 Tohoku and various other smaller tsunamis of the past 15 years. Important components were the application of local parallelization using GPUs to achieve significant speed-ups for the numerical simulation of tsunamis compared to conventional technologies (independent of high performance computing) and the use of machine learning techniques to assess potential maximum earthquake magnitudes and empirical inundation patterns.

Mr. Niklas Thiel

In April 2018 M.Sc. Niklas Thiel successfully defended his PhD thesis

Title: Acoustic and elastic FWI of marine dual-sensor streamer data in the presence of salt
Supervisors :
Prof. Dr. Thomas Bohlen (KIT)
Apl. Prof. Dr. Joachim Ritter (KIT)

The aim of his research was the investigation of elastic effects in marine towed-streamer data for full-waveform inversion (FWI). In general, the acoustic approximation of FWI is used for these kind of data because S-waves do not propagate in water and elastic effects are assumed to be small.

MISCELLANEOUS

AWARDS:

The Deutsche Geophysikalische Gesellschaft (DGG) awarded two prizes for presentations from members of GPI at the 78th annual meeting in Leoben.

Valérie Krampe (MSc student, Applied Geophysics) and **Michael Grund** (PhD student, Seismology) have been honoured for their presentations during the 78th Annual Meeting of the German Geophysical Society (DGG) in Leoben (Austria). Valérie was awarded for the best poster presentation of young scientists for her poster "Effects of seismic anisotropy on near-surface full-waveform inversion". Michael received an award for the best oral presentation with the title "Observation of lowermost mantle anisotropy beneath the East European Craton and at the northern edge of the African LLSVP".

With a KIT grant for young scientists and international networking, **Michael Grund** spent one week at Yale University in April. There he worked with the group of Maureen Long on seismic anisotropy in the deep mantle.

At the same DGG conference **Dr. Ellen Gottschämmer** received the newly established teaching award from the DGG. This award honors her great engagement in academic teaching and the excellent evaluations Dr. Gottschämmer received during the last years.

The new lecture „Reflection Seismics“ taught by **Dr**. **Thomas Hertweck** received the best evaluation of all lectures of the KIT-Department of Physics in the winter term 2017/18. In the list of the top ten of evaluated lectures you also find the GPI lecture „Physics of seismic instruments“ by **Dr. Thomas Forbriger**. Furthermore, the following exercises received top ratings: "Introduction into Geophysics" by **Ellen Gottschämmer** and **Niklas Thiel**, "Array Processing" by **Michael Grund** and **Toni Zieger**, “Reflection Seismics" by **Thomas Hertweck, Tilman Steinweg** and **Renat Shigapov.**

M.Sc. Toni Zieger, who studies seismic emissions from wind turbines, used his KIT grant for young scientists and international networking for a visit at Keele University. There he worked with the group of Peter Styles which did pioneering work on seismic signals from wind turbines.

WORKSHOPS

FWI workshop Leoben

The Applied Geophysics group has co-organized the 3rd workshop “Near-surface full-waveform inversion (FWI)” in Q4/2017 at the Montanuniversität Leoben, Austria. Various participants from ETH Zürich (Switzerland), Forschungszentrum Jülich (Germany), Université Grenoble Alpes (France), KIT, and Montanuniversität Leoben attended this workshop. Twelve presentations were given during the workshop, all of which mainly focused on the theory and application of FWI on shallow seismic or ground penetrating radar (GPR) data. The attendees discussed scientific questions on (elastic) FWI in great detail and agreed to hold the 4th workshop in February 2019 at the Forschungszentrum Jülich.

NEW EMPLOYEES

Since 1st March **M.Sc. *Sarah Mader*** is working at GPI. Sarah did her master's degree at the University of Kiel. Then she worked as scientist at the University of Hamburg. Now she is doing a study on local earthquakes and tectonic stress in the northern foreland of the Alps. This study is part of the DFG SPP2017 Mountain Building Processes in 4 Dimensions and the international AlpArray experiment. See also:http://www.gpi.kit.edu/english/StressTransfer.php

Since 5th February ***M.Sc. Sergio Leon-Rios*** is working at GPI. Sergio got his Physics bachelor's degree at the Catholic University of the North in Antofagasta, Chile. Then he moved to Santiago where he did his master's degree in Geophysics at University of Chile.
In 2016 he started his PhD at the University of Liverpool in the United Kingdom. After two years Sergio joined GPI to continue with his research focus on the analysis of subduction earthquakes. The main goal of this project is to get a 3D tomography based on the aftershock sequence of the 2016 Mw 7.8 Pedernales, Ecuador earthquake.

You can follow him on twitter: @topoleonrios to check updates about earthquakes and volcanoes mostly in Chile and South America.

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Issue 13, July 2018

Excursion

In July the Department of General Geophysics went canoeing on the idyllic river Ens. The tour started in Bietigheim-Bissingen and ended in Walsheim at the river Neckar. With beautiful weather and wonderful landscape all had a great time and a lot of fun.

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GUESTS

Ph.D. Candidate Ms. *Nesrin Yenihayat* from Bogazici University Kandilli in Turkey studying at the Observatory and Earthquake Research Institute-KOERI visits GPI from March 2018 to September 2018. Her work is focused on the validation of modelled earthquake losses with historic data from the city of Erzincan located in the Eastern Part of Turkey.

In May Dr. Saskia Goes from the Imperial College in London visited GPI to give a lecture about "Thermo-chemical structure of cratonic lithosphere: constraints from seismic velocity and heat flow."

RECENT PUBLICATIONS

In this section we would like to inform those of you who are still active in Geophysics about recently published peer-reviewed journal papers authored by current members of GPI:

Aydin N.Y., Duzgun H.S., Wenzel F., Heinimann H.-R.: Integration of stress testing with graph theory to assess the resilience of urban road networks under seismic hazards, Nat Hazards (2017). doi.org/10.1007/s11069-017-3112-z

Wenzel F.: Fluid-induced seismicity: comparison of rate- and state- and critical pressure theory, Geotherm Energy (2017) 5:5, doi:10.1186/s40517-017-0063-2

Leder J., Wenzel F., Daniell J. E., Gottschämmer E.: Loss of residential buildings in the event of a re-awakening of the Laacher See Volcano (Germany), Journal of Volcanology and Geothermal Research, 2017.

Tsang H.-H., Daniell J.E., Wenzel F., Werner A.C.: A semi-probabilistic procedure for developing societal risk function, Nat Hazards, https://doi.org/10.1007/s11069-018-3233-z,2018.

Zieger T., Ritter J. R.R.: Influence of wind turbines on seismic stations in the upper Rhine graben, SW Germany, J. Seismol, 22, 105-122, 2018.

Gao L., Pan Y., Tian G., Xia J.: Estimating Q factor from multi-mode shallow-seismic surface waves, Pure and Applied Geophysics, doi 10.1007/s00024-018-1828-7, 2018.

Gao L., Pan Y.: Source signature estimation from multimode surface waves via mode-separated virtual real source method: Geophysical Journal International, 213, 1177-1186, 2018.

Kurzmann A., Gassner L., Shigapov R., Thiel N., Athanasopoulos N., Bohlen T., Steinweg T.: Real Data Applications of Seismic Full Waveform Inversion, in Nagel W., Kröner D., and Resch M. (Ed.), "High Performance Computing in Science and Engineering '17", Springer, 467-484, 2018.

Pan Y., Gao L., Bohlen T.: Time-domain full-waveform inversion of Rayleigh and Love waves in presence of free-surface topography, Journal of Applied Geophysics, 152, 77-85, 2018.

Foti S., Hollender F., Garofalo F., Albarello D., Asten M., Bard P.-Y., Comina C., Cornou C., Cox B., Di Giulio G., Forbriger T., Hayashi K., Lunedei E., Martin A., Mercerat D., Ohrnberger M., Poggi V., Renalier F., Sicilia D., Socco V.: Guidelines for the good practice of surface wave analysis: a product of the InterPACIFIC project. Bulletin of Earthquake Engineering, 4. Sep. 2017, 1-54, (doi: 10.1007/s10518-017-0206-7), 2018.

Bee L., Hicks S., Garth T., Gonzalez P., Rietbrock A.: Two go together: Near-simultaneous moment release of two asperities during the 2016 Mw 6.6 Muji, China earthquake, Earth and Planetary Science Letters, 491, pp. 34-42, 2018.

Coulson S., Garth T., Rietbrock A.: Velocity Structure of the Subducted Yakutat Terrane, Alaska: Insights From Guided Waves, Geophysical Research Letters, 45 (8), pp. 3420-3428, 2018.

Allen R.W., Berry C., Henstock T.J., Collier J.S., Dondin F.J.-Y., Rietbrock A., Latchman J.L., Robertson R.E.A.: 30 Years in the Life of an Active Submarine Volcano: A Time-Lapse Bathymetry Study of the Kick-'em-Jenny Volcano, Lesser Antilles, Geochemistry, Geophysics, Geosystems, 19 (3), pp. 715-731, 2018.

Feng M., Bie L., Rietbrock A.: Probing the rheology of continental faults: decade of post-seismic InSAR time-series following the 1997 Manyi (Tibet) earthquake, Geophysical Journal International, 215, pp. 600–613, 2018.

Feedback

If you have any comments, questions or remarks, please do not hesitate to contact us. We appreciate your feedback.