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NEWSLETTER OF THE GEOPHYSICAL INSTITUTE

Issue 15, August 2019

DEAR GPI ALUMNI

In the first half of 2019, GPI was reaching for the stars. Our joint Black Forrest observatory was heavily involved in the Mars InSight mission, landing a broadband seismometer on Mars. First data is now coming in and there already have been the first few Marsquakes recorded. Then towards the end of the semester, our Alumni Dr. Alexander Gerst, Astro-Alex, was awarded with the honorary doctorate of the KIT-Departments of Physics as well as Civil Engineering, Geo and Environmental Sciences. Alex visited GPI; met some "old friends" and our current students had the chance to talk to him directly. Additionally, there is a lot interesting research and teaching going on at GPI, as you can see from the articles in the current newsletter. Finally, after all this excitement in the first half on 2019, a well-earned summer break is needed and I wish everybody joyful summer holidays.

Andreas Rietbrock

TEACHING

By Ellen Gottschämmer

The transformation of the KIT Geophysics master program into an English degree course has increased the number of applicants for this summer semester drastically. Almost 100 applications were received for summer semester 2019, most of them from international students. About a third of the applicants fulfilled the requirements to be admitted. This involves a certain number of credits in Maths, Physics and Geophysics from a previous Bachelor's Degree, and excellent English skills. Not all of the students admitted could make it to Karlsruhe in time, so we started with nine new foreign students and several students from KIT into the summer semester. Teaching such a diverse group can sometimes be challenging! This is not only because all students bring different prior knowledge – also in computing which is not included in the official requirements - but also because students have a completely different learning culture. Bringing the students together in hands-on-exercises and during in situ lectures might help to reduce the gaps and converge to a common base.

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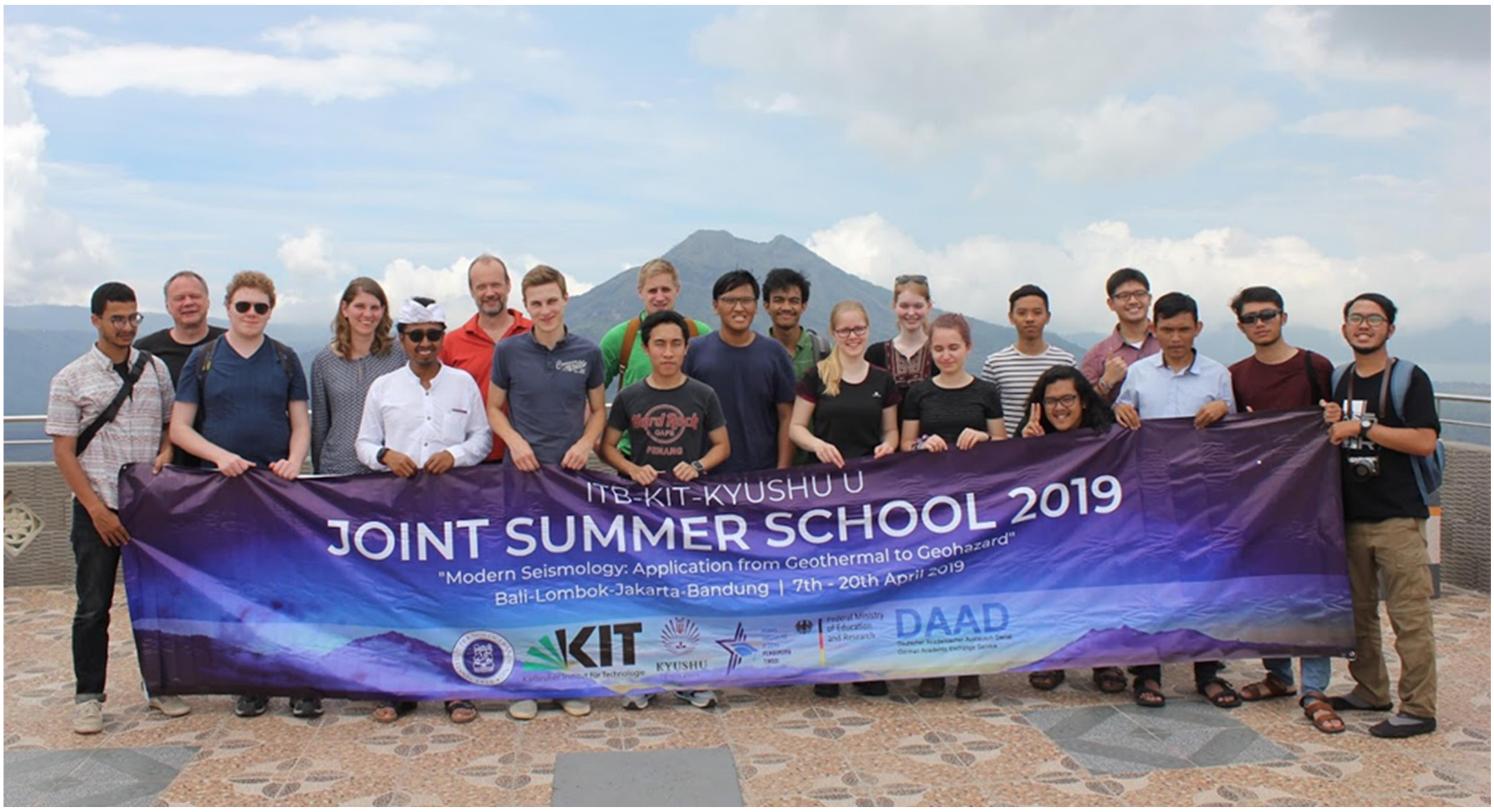
In March, our first in situ lecture for 2019 took place in Strasbourg and parts of the Upper Rhinegraben. Despite awkward weather, students tried to find an answer to the question how historical seismological and other records can help to assess seismic hazard in the Upper Rhinegraben. Just one month later, in April, we conducted a summer school for Indonesian and German (as well as one French!) students on Lombok, Bali and Java. The summer school covered topics from Seismology, Geothermal as well as from Natural Hazards and included the visit of geothermal areas, locations affected by the Lombok 2018 earthquakes on Lombok Island, and some volcanoes on Bali and Java. Participants worked together in internationally mixed teams and read and discussed research papers, which they had to present at the end of the two-week program. A third in situ lecture this year was exclusively held for our students in the Geophysics master program: In Thuringia we studied induced seismicity from mines and reservoir dams which included also a visit to a deep (800m) potash mine. This was not only valuable in terms of gaining new knowledge but also regarding group dynamics. The students of our Bachelor program were in turn able to visit BFO for a day in July and found out what makes BFO such a special place. Because we believe that BFO is also an interesting place to visit for Physics' students they were equally invited to take part in this in situ lecture.



Summer School Indonesia: At Batur volcano (Bali). Photo by Emmanuel Gaucher (AGW, KIT)

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APPLYING THE LATEST DEVELOPMETNS IN MACHINE LEARNING/ARTIFICAL INTELLIGENCE TO SEISMIC DATA MINING

By Jack Woollam and Andreas Rietbrock

Recent developments in the field of Artificial Intelligence (AI) and Machine Learning (ML) have transformed numerous fields ranging from computer vision to natural language processing. Having recently been introduced to seismology, these methods are now demonstrating exceptional performance in solving a variety of seismological tasks. The detection and association of seismic events is one such area where the adoption of AI/ML algorithms has significantly improved performance when compared against historic methods. Our research aims to further investigate the potential of such techniques for improving seismic data recovery. This article contains a summary and run-through of our recent work at The Geophysical Institute.

ML methods can be described as a specific suite of artificial intelligence algorithms which learn from experience without requiring a set of explicitly programmed rules. Whilst many of these techniques have been around for decades, a recent resurgence has occurred due to the continued increase in both computational power and volume of data available. Having a greater number of examples to statistically infer from results in ML methods making more accurate predictions. Within seismology, massive data catalogues of labelled event arrivals are readily available (IRIS catalogue size >500TB as of 31/12/2018). So, there exists huge potential for 'data-driven' ML approaches to improve seismic event detection.

Event picking

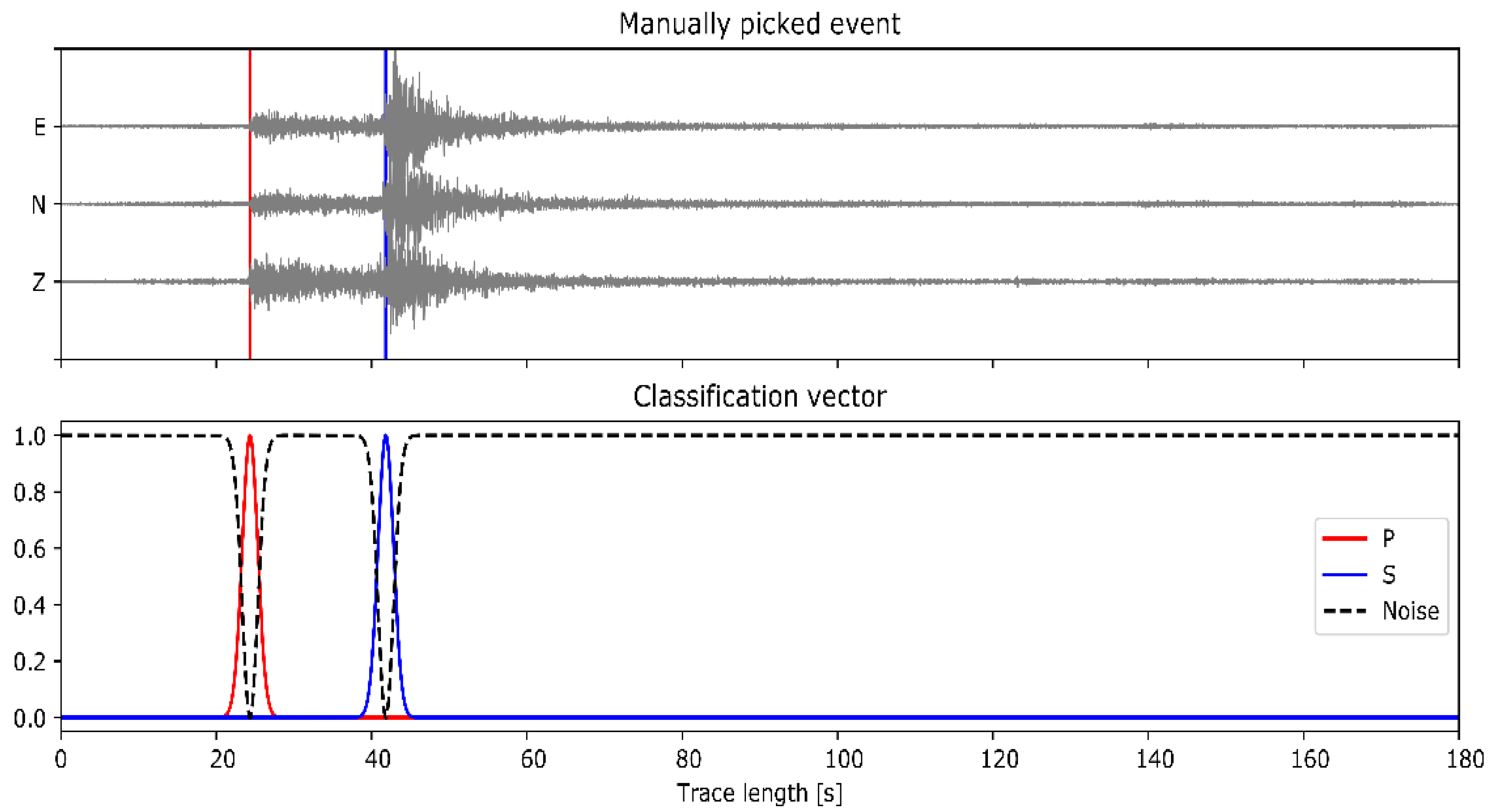

Figure 1 | Example of a P- and S-phase pick for a seismic trace, the classification vector is created by probabilistically representing the P and S phase picks, these are then used in training the CNN.

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To investigate the feasibility of such techniques for data recovery, we first focused on the fundamental problem of seismic picking. Our training dataset consisted of 411 manually picked seismic events throughout northern Chile. In total ~11,000 manual P- and S-phase onsets were used for training (Fig. 1), this is relatively small for ML purposes. We applied a Convolutional Neural Network (CNN) to the training dataset. As a brief summary, a CNN is a technique which applies repeated convolutional and pooling operations to input data, resulting in a set of learnable filters which automatically engineer the appropriate features for the classification task. By learning representations of the input data, where multiple layers provide varying levels of abstraction, CNNs demonstrate super-human performance when classifying images, videos, and audio files. For our task, the CNN seeks to extract the appropriate features of a seismic trace to classify P-phase onsets, S-phase onsets, and Noise. We compared our results against the widely used STA/LTA picking approach, which detects phases using the ratio of the manually extracted ratio short-term energy over long-term energy (Fig 3.).

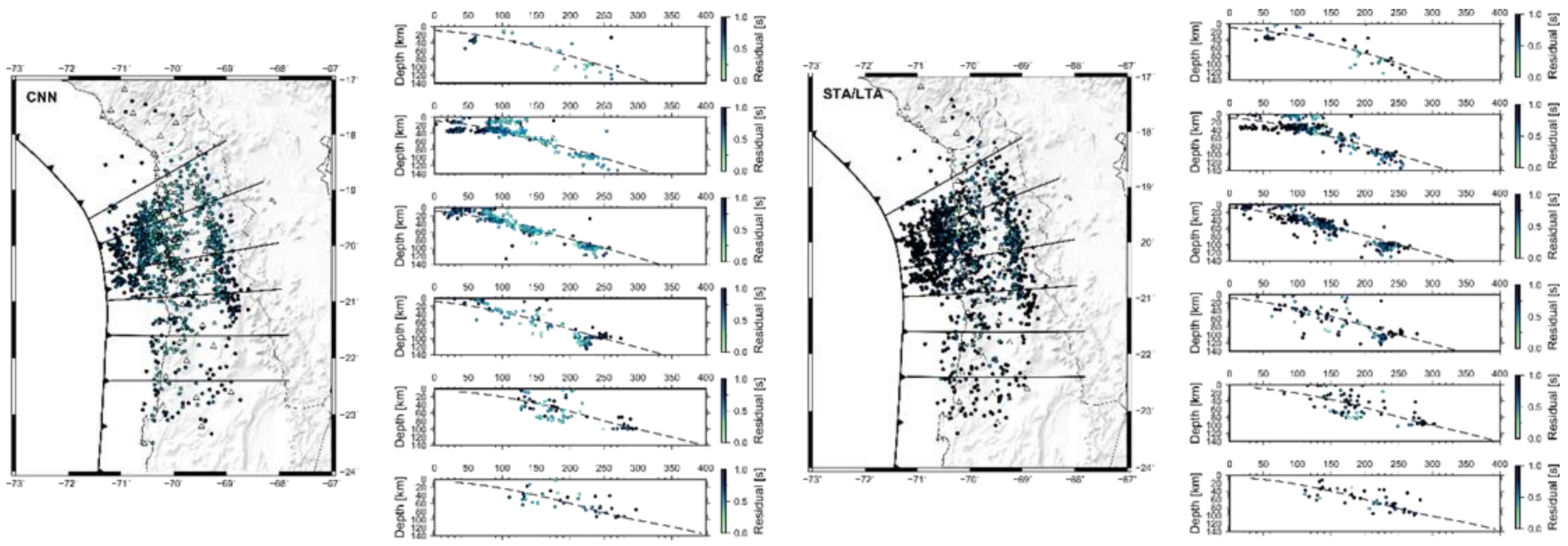

Figure 2 |Comparison of hypocentral relocations for events picked using the historic STA/LTA approach (right-hand-figure) which uses manual feature extraction, against events picked using the CNN (Left-hand-figure). In both plots, events are coloured a function of RMS residual.

The events picked using the CNN approach exhibit a lower relocation residual, and better delineate the slab structure, indicating lower relocation errors. In comparison, the traditional STA/LTA picked events had a higher residual (darker colours) and poorer relocation errors. Our results further demonstrate the promise of ML/AI methods for seismic phase picking even in the limiting case of a relatively small, biased training dataset.

Event association

The adoption of AI/ML methods for seismic phase picking, along with continued developments in seismic sensors generate a step change in both the volume and accuracy of pick catalogues; all these deterministic picks, however, still need to be correlated to their underlying event.

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This problem is non-trivial as an unknown number of sources occurring simultaneously produce overlapping events, and there is also the problem of numerous false picks (Fig 3.). This is the second component of our development of a robust seismic event detection pipeline and is a major focus of our current research

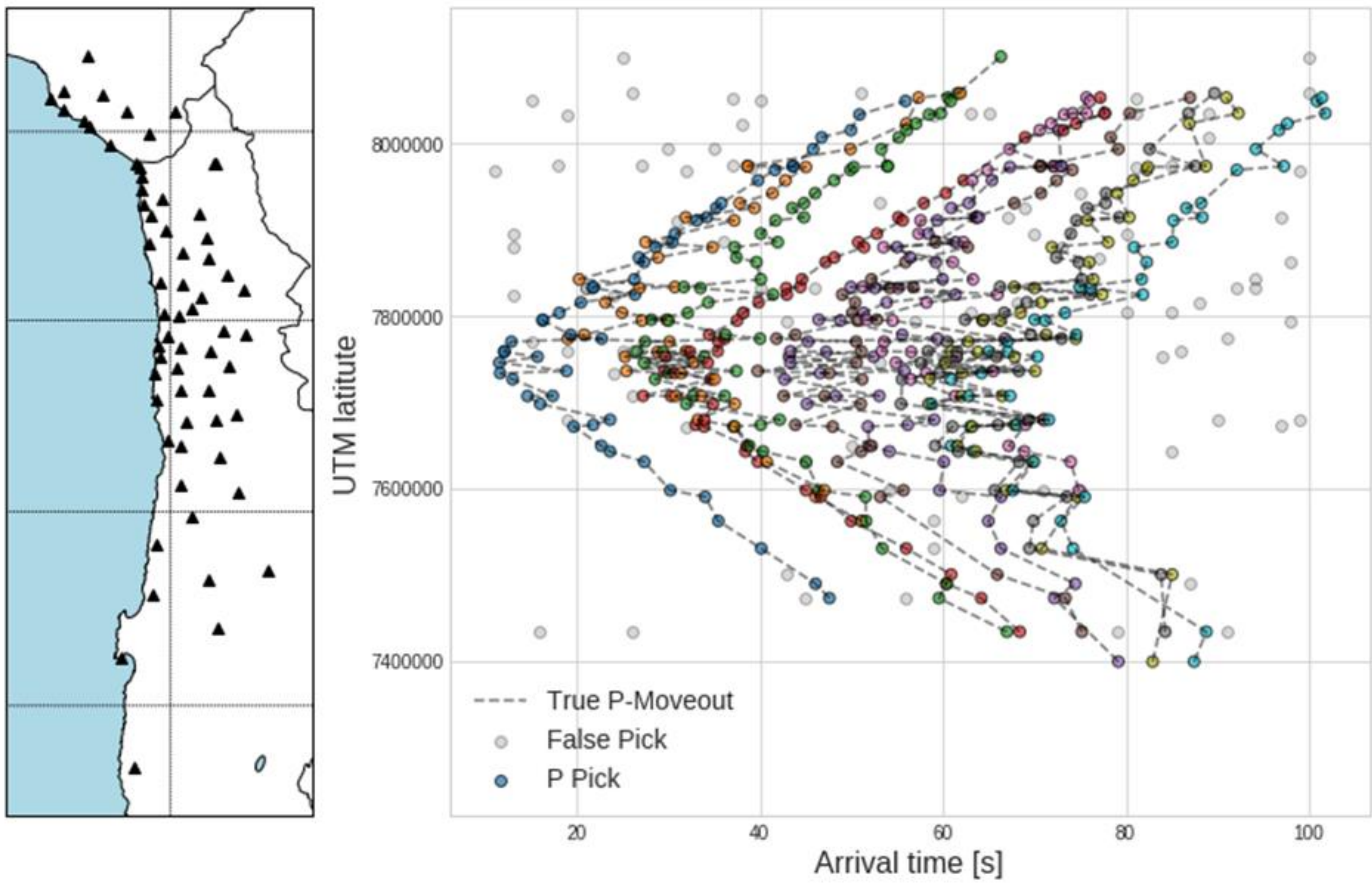

Figure 3 | An example of some synthetic events, simulating the phase association problem. The wavefield propagation has been forward modelled and event arrivals are calculated for the northern Chilean receiver distribution (Left-hand-side plot). Synthetic P-phase arrivals are coloured a function of the underlying true association (right-hand-side plot), false picks are added in grey.

The typical approach to seismic phase association is to apply a grid-based association routine, where the region is parameterised, and onsets are back-projected to check which originated from the same coherent source. These associators often require significant tuning, along with many input parameters and they break down when the seismicity rate is high. We are finalising a method where we adopt a ML technique extensively used in the computer vision community and apply it to the seismic phase association problem. This technique performs robust parameter estimation in the presence of a large proportion of outliers.

The accurate correlation of smaller, more frequently occurring events is of huge potential benefit seismologists investigating the physical processing associated with large megathrust ruptures. The pre- and post- seismic period currently contains seismicity which is beyond the resolving capability of all currently employed association algorithms. Accurately relocating the seismicity occurring during this period will hopefully greatly enhance the understanding surrounding these events.

This was just a brief summary of the major topics we are currently working on. The publication of our autopicking approach can be found here: https://doi.org/10.1785/0220180312

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INTERNATIONAL COLLABORATION DEPLOYED LARGE SEISMIC MONITORING NETWORK IN NORTHERN CHILE

By Sergio León-Ríos

As part of a collaboration project between GPI and the Geophysical Department (DGF) of Universidad de Chile, a large temporary network for seismicity monitoring was deployed in central Chile, just in the area where a M6.7 earthquake occurred on the 20th January 2019. The data obtained with these instruments before, during and after the main shock will help to a better understanding of what could trigger this event. This installation is part of the ANDES project (Agua Negra Deep Experiment Site) in which the geophysical section (ANDES-GEO) aims to be the first in-depth laboratory constructed under 1750 m below an active orogene as the Andes mountain range. The deploying that includes 88 temporary stations was separated in two parts: the first during December 2018 where 35 stations were buried in the Atacama region, covering an area that extends from the Pacific to the Andes. Then, the second part of the installation was completed at the beginning of January 2019, where another group deployed other 53 stations in the Copiapó region.

Deployment team. Photo by León-Ríos

Regarding the participants of the campaign, in December two former DGF students, Valentina Reyes-Wagner and Sergio Léon-Ríos, attended along with Daniela Calle (member of the Advanced Mining and Technology Center of Universidad de Chile) and Francisco Pasten (PhD student of Universidad Catolica del Norte), who was at the time in a short investigation stay at GPI. January's campaign was carried out by Daniela Calle and Andrea Paz Navarro-Aranguiz (Master student at DGF) who also visited us for a short internship.

Source: http://www.dgf.uchile.cl/noticias/151523/proyecto-internacional-instala-mas-de-80-estaciones-sismologicas

Station configuration before burring it into the field.
Photo by León-Ríos

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FROM THE BLACK FOREST TO MARS - AN INSIDERS REPORT FROM 6 WEEKS AT JPL

By Rudolf Widmer-Schnidrig, Black Forest Observatory (BFO)

At the Black Forest Observatory (BFO) we have been involved in tests of prototype seismometers for the joint European/American InSight Mission to Mars since 2012. This involvement culminated in a six week long stay at NASA's Jet Propulsion Laboratory in Pasadena in late 2018 and early 2019. The following is a personal account of this occasion and events leading up to it.

The development of hardware for space missions is a long process: Philippe Lognonnée, the principal investigator (PI) of the seismometer for this mission worked 25 years on building a seismometer for deployment on Mars and on getting it there. Verifying the performance of the seismometer under low-noise conditions and comparison against established standards was the specific expertise that BFO could contribute. In 2017, after several prototypes had been tested in the mine at BFO I traveled to the French space agency (CNES) in Toulouse with equipment from BFO to participate in a huddle test. So I was asked to set up an STS-2 seismometer in a clean room next to the flight model of the InSight seismometer - the one that is now installed on the surface of Mars (picture). In May 2018 the science team meeting #12 was held in Santa Barbara California and we could all go to Vandenberg air force base to watch the launch of the Atlas V rocket carrying InSight. Launch was at four in the morning and we stood in dense coastal fog from the nearby Pacific Ocean: no fiery display across the night sky - just a distant deep and long lasting roar. Still we were all relieved to have made it this far – it was a bumpy road - and we were energized for the mission ahead.

Huddle test: InSight seismometer installed next to reference STS-2. Photo by CNES/Toulouse

Six months later the space craft arrived at Mars and the landing could be followed live on TV. I was invited to JPL in Pasadena to support and advise during the deployment and commissioning of the seismometer. Of course I asked myself: what can I contribute to this mission that the JPLers cannot do on their own? What do you want to tell the engineers and scientists who navigate a space craft between Saturn and its rings? It turns out very few people have experience with installing broad band seismometers and that is where I could contribute.

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Another aspect was that I know Philippe Lognonée, for a long time - we did our thesis at the same time and almost on the same topic. So it was also my role to sometimes challenge Philippe, to not be intimidated by the PI's opinion and for the sake of getting a good discussion going take on a provocative opposing stance.

While the media were full of reports about the successful landing on Mars nobody reported that hours after the landing when the first window opened to reestablish communication, the lander remained silent! These were tense times and the foreign scientists working on the payload only got a tiny fraction of the information about the evolving situation. There was also very little we could do. Now this is not the first time NASA loses contact with a space craft and they were very well prepared for this situation. If the lander cannot establish communication it is programmed to go into a safe mode in which the first priority is to save electric power and the second one is to give the engineers time to assess the situation and come up with a strategy to fix the issue. So to save power the time between wake ups of the lander rapidly increased (and we saw our schedule for the seismometer deployment shift further and further back). Well, as it turned out the temperature encountered at the landing site was lower than had been expected. One consequence of this cold temperature was that the X-band antenna contracted more than expected. This in turn changed the frequency characteristics of the antenna and detuned it. So the lander was not silent but it transmitted in the wrong frequency band – not the one in which the radio telescopes on Earth were programmed to listen. With this explanation in hand it was easy to come up with a fix: just tell the radio telescopes to listen in a wider frequency band. And yes – communication could be reestablished. Needless to say that we were all very much relieved.

Already while the seismometer was still on the deck of the lander we – the members of the science team - started to have daily Data Analysis Meetings (DAMs) where we analyzed the first precious snippets of data from Mars. To me this was not unfamiliar: we wanted to make sense out of signals from a diverse set of sensors: seismometer, barometer, magnetometer, tilt meters, thermometers. What physical event can be made responsible for these simultaneous signals? Solving this kind of puzzle is something we often do at BFO. We had to convince ourselves that the three broad-band (VBB) and three short period (SP) seismometer components were operating properly. We had to make sense out of signals that none of us had seen before: no marine microseisms, no tidal signals, none of the known and familiar background noises as we know them from Earth. These were very memorable meetings. For redundancy a triplet of British made MEMS SP seismometers are also included in the SEIS package. MEMS seismometers are cheaper, lighter, less sensitive but also more robust than the VBBs. So they could be turned on while SEIS was still on the deck. And poor Philippe (responsible for the VBB) had to wait not just days but weeks before his seismometer got turned on. Thus eloquent Tom Pike, being responsible for the SP, got many chances to proudly presented the data from *his* SP seismometer while Philippe was watching almost empty handed. I have to admit that secretly many of us hoped that the first Mars quake would not come just yet.

The French VBB vs. British SP competition was just one ingredient why we had very lively and engaging discussions on how to interpret the signals that we got.

The two cameras on board the lander started to image the surrounding right after the landing. With these images a 3D digital terrain model was generated to aid in the site selection for the SEIS seismometer package. In fact this terrain model was transferred into a large indoor sand box in a laboratory building at JPL where also a duplicate of the lander stood. Here we could watch as the robotic arm movements got optimized to lift the SEIS package from the deck and place it at the desired location on Mars.

Meanwhile the SEIS instrument package is deployed next to the lander and protected by a wind and thermal shield (picture). The commissioning phase has been successfully completed and continuous 24bit broad-band data is being recorded and transmitted to Earth at a rate of 20 samples per second. The members of the science team are now busy writing the first papers and what I can say is that all sensors perform as expected. The data set is very rich. Seismicity: the seismometer stands in the wind on a soft surface. That is far from optimal particularly for someone who is used to install seismometers on granite. However every Sol there are also quiet times with low wind where small quakes have been detected. Mars is in size somewhere between Moon and Earth and for the quake signals recorded so far I can say that they are more Moon-like: thus emergent signal onsets and long scattering coda as has been seen in the lunar seismograms collected by the Apollo mission 50 years ago. However, the largest quake so far also shows distinct P- and S-waves. Fellow alumni Maren Böse has her own story to tell about that particular quake. Atmosphere: The barometer recordings are very rich at all time scales: thermal tides at daily periods, gravity waves at 5-15 minute periods, and dust devils at 1 - 30 seconds to mention just the most ubiquitous phenomena. Magnetic field: every activity of the lander also shows up in this dataset and much cleaning is needed before it can be interpreted. Nonetheless preliminary interpretation of concurrent surface (InSight) and satellite magnetic field recordings seem to favor a highly conductive subsurface that leads some to speculate about a brine rich martian crust. Finally the atmospheric temperature: its daily variation is from -95C to 0C and it is slowly getting colder as Mars moves on its elliptical orbit away from the Sun.

Certainly the coming years will be very interesting with all the new and exciting geophysical data coming down from our planetary neighbor Mars.

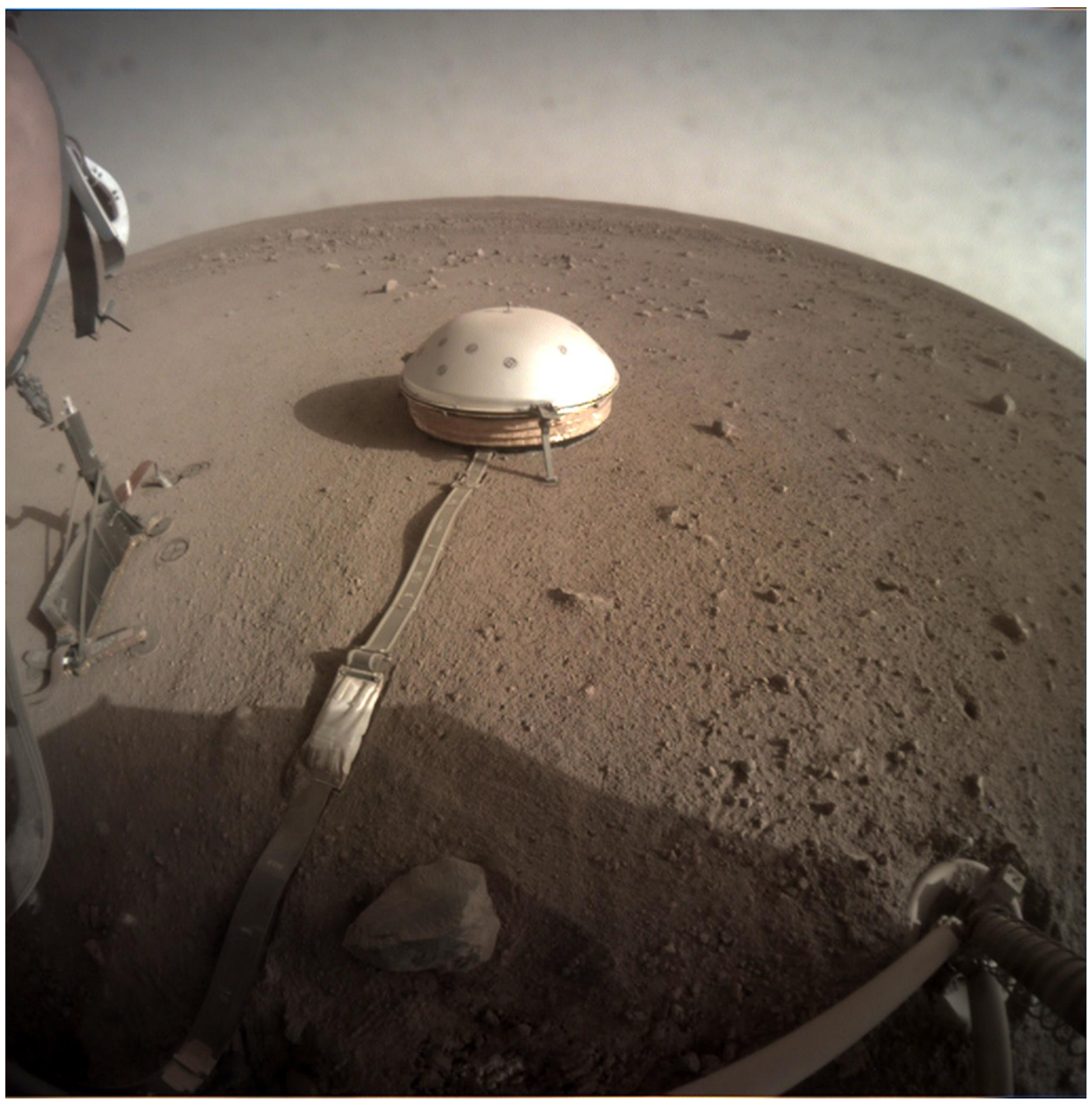

Photo by JPL/NASA

ALUMNI ALEXANDER GERST – HONORARY DOCTORATE AT KIT

By Joachim Ritter

Our alumni and ESA astronaut Dr. Alexander Gerst, Astro-Alex, was awarded with the honorary doctorate of the KIT-Departments of Physics as well as Civil Engineering, Geo and Environmental Sciences. On 12th July 2019 Alex visited KIT and there was an official ceremony in the Audimax which was completely crowded. Alex gave a wonderful talk on his two space missions *Blue Dot* and *Horizons* in the International Space Station (ISS). His photos of the Earth, taken from the ISS, nicely document the beauty and fragility of our environment. Afterwards Alex visited the GPI for a reception and spoke with geophysics students and employees.

Here are some impressions:

All photos by Annika Müller KIT

PhD at GPI

In February 2019 M.Sc. **Michael Grund** successfully defended his PhD thesis.

Title: ***"Exploring geodynamics at different depths with shear wave splitting"***

Supervisors:
Apl. Prof. Dr. Joachim Ritter (KIT)
Prof. Dr. Andreas Rietbrock (KIT)

The main goal of his research was to characterize the anisotropic structure beneath the Fennoscandian peninsula as well as in the Earth's lowermost mantle based on a uniformly processed data set provided by the ScanArray network. For this purpose single-event shear wave splitting analysis was performed using core-refracted shear waves (*SKS*, *SKKS*, *PKS*) of around 3000 globally distributed teleseismic earthquakes. The massive seismic data set provided a comprehensive characterization of the distinct lateral and backazimuthal variations of the shear wave splitting pattern at individual stations and across the ScanArray network. Furthermore, his results shed light on lowermost mantle anisotropy located in the D" layer beneath the North Atlantic and northwestern Siberia.

In July 2019 M.Sc. **Toni Zieger** successfully defended his PhD thesis.

Title: ***"Experimental quantification of seismic signals induced by wind turbines"***

Supervisors:
Apl. Prof. Dr. Joachim Ritter (KIT)
Prof. Dr. Andreas Rietbrock (KIT)

The aim of his research was to investigate the influence of wind turbines (WTs) on seismic recordings. WTs induce vibrations through the foundation into the subsurface, where these vibrations propagate as seismic waves to nearby seismic stations. In order to investigate the influence of the local subsurface on the amplitdecay behavior of the induced seismic signals the study analyzes recordings of more than twenty measurements campaigns at several single WTs and wind farms, focussing on different geological settings. The results show an impact of WT-induced signals on recordings of seismic stations in the frequency range from 0.1 Hz to 20 Hz up to 9 km distance away relative from the location of the WTs. This specific range is highly important for the detection of local earthquakes or the monitoring of the Comprehensive Nuclear-Test-Baude n Treaty (CTBT).

MISCELLANEOUS

Michael Grund received the Bernd Rendel-Preis 2019 of the German Research Foundation (DFG) for his promising and original geoscientific research. This prize is given to extraordinary research of young scientists. Michael achieved high quality results within a broad spectrum of seismological and geoscientific research and he published his achievements in renowned journals.

Thomas Hertweck came first in the category "Best lecture overall" in the faculty's lecture evaluations for winter semester 2018/19. During the last Physics colloquium and award ceremony, the dean of the faculty presented him a certificate for his lecture "Seismics" and a nice bottle of wine.

Guests at GPI

Mr Francisco Pasten-Araya

Mr. Pasten-Araya a PhD candidate from the Universidad Católica del Norte and the Universidad de Chile, Dr (c) Francisco Pasten-Araya, visited GPI for three months, from October 10th, 2018 until January 10th, 2019. The aim of his stay at GPI, was to present the results of his 3D seismic tomography research and analysis of the microseismicity of the Mejillones Peninsula, in northern Chile, and thus continue working on these topics in the future with Prof. Andreas Rietbrock. Another of its objectives was to strengthen a line of collaboration between the Universidad de Chile and GPI to establish future networks of scientific collaboration between both institutions.

Ms Andrea Paz Navarro Aranguiz

As part of the Internship Grant program supported by KHYS, Ms Andrea Paz Navarro-Aranguiz, master student at the Geophysical Department at Universidad de Chile, visited GPI from March 2019 till May 2019. She was under the supervision of our PhD student Sergio Leon-Rios and Prof. Andreas Rietbrock and joined our working group on Seismology and Geophysics. During her stay, Andrea tested the performance of an automatic seismic phase detector algorithm using data coming from the PICTURES project in northern Chile.

You can find more information on this link: http://blogs.oregonstate.edu/pictures/

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:

Brunke H.-P., Widmer-Schnidrig R., Korte M.: Merging fluxgate and induction coil data to produce low-noise geomagnetic observatory data meeting the INTERMAGNET definitive 1 s data standard. GEOSCÌENTIFIC INSTRUMENTATION METHODS AND DATA SYSTEMS Volume: 6, Issuce: 2, Pages:487-493, DOI:10.5194/gi-6-487-2017, 2017.

Spiga A. and the Insight science team.: Atmospheric Science with InSight SPACE SCIENCE REVIEWS Volume: 24, Iss 24, Issue:7. DOI:10.1007/s11214-018-0543-0, 2018.

BFO-Team: Duffner P., Forbriger Th., Heck B., Westerhaus M., Widmer-Schnidrig R. und Zürn W.: Das Geo-wissenschaftliche Gemeinschaftsobservatorium Schiltach (BFO). In: Festschrift zur 150-Jahr-Feier des Geodätischen Instituts (1868 - 2018). Kurt Seitz (ed.). Karlsruher Institut für Technologie (KIT), Schriftenreihe des Studiengangs Geodäsie und Geoinformatik, 2018-2. KIT, Scientific Publishing. 255-274. (doi: 10.5445/KSP/1000086360), 2018.

Forbriger Th., Heck A.: Frequency response of the superconducting gravimeter SG 056. In: Festschrift zur Ver-abschiedung von Prof. Dr.-Ing. Dr. h.c. Bernhard Heck. Karlsruhe Institute of Technology (KIT), Karlsruhe. 57-67. (doi: 10.5445/KSP/1000080212), 2018.

Hetényi G., Molinari I., Clinton J., Bokelmann G., Bondár I., Crawford W.C., Dessa J.-X., Doubre C., Friederich W., Fuchs F., Giardini C., Gráczer Z., Handy M.R., Herak M., Jia Y., Kissling E., Kopp H., Korn M., Margheriti L., Meier T., Mucciarelli M., Paul A., Pesaresi D., Piromallo C., Plenefisch T., Plomerová J., Ritter J.R.R., Rümpker G., Šipka V., Spallarossa D., Thomas C., Tilmann F., Wassermann J., Weber M., Wéber Z., Wesztergom V., Živčić M.: AlpArray Seismic Network Team, AlpArray OBS Cruise Crew and AlpArray Working Group. The AlpArray Seismic Network: a large-scale European experiment to image the Alpine orogen. Surv. Geophys., 39, 1009-1033, 2018.

Hensch M., Dahm T., Ritter J.R.R., Heimann S., Schmidt B., Stange S.,Lehmann K.: Deep low-frequency earthquakes reveal ongoing magmatic recharge beneath Laacher See Volcano (Eifel, Germany). Geophys. J. Int., 216, 2025–2036, 2019.

Grund M., Ritter J.R.R.: Widespread seismic anisotropy in Earth's lowermost mantle beneath the Atlantic and Siberia, Geology, 47, 123-126, 2019.

Schäfer A. M., Wenzel F.: Global Megathrust Earthquake Hazard—Maximum Magnitude Assessment Using Multi-Variate Machine Learning, Frontiers in Earth Science 7, June 2019, DOI: 10.3389/feart.2019.00136, June 2019.

Nagel S., Zieger T., Luhmann B., Knödel P., Ritter J.R.R., Ummenhofer Th.: Erschütterungsermissionen von Windenergieanlagen, Stahlbau 88, Heft 6, 559- 573, 2019.

Gassner L., Gerach T., Hertweck T. and Bohlen T.: "Seismic characterization of submarine gas-hydrate deposits in the Western Black Sea by acoustic full-waveform inversion of OBS data", Geophysics, 84(5), 1-49, 2019.

Pan Y., Gao L., Bohlen T.: "High-resolution characterization of near-surface structures by surface-wave inversions: from dispersion curve to full waveform", Surveys in Geophysics, 40(2), 167-195, 2019.

Thiel N., Hertweck T., Bohlen T.: "Comparison of acoustic and elastic full-waveform inversion of 2D towed-streamer data in the presence of salt", Geophysical Prospecting, 67(2), 349-361, 2019, 2019.

Schroth E., Forbriger Th., Westerhaus M.: A catalogue of gravimetric factor and phase variations for twelve wave groups. KIT Scientific Working Papers, 101. Karlsruhe Institute of Technology (KIT). (doi: 10.5445/IR/1000089609), 2019.

An folgenden Publikationen war Ruedi Widmer-Schnidrig (BFO-Mitarbeiter und GPI-Alumnus) beteiligt:

Lognonne P. and the Insight science team, SEIS: Insight's Seismic Experiment for Internal Structure of Mars. SPACE SCIENCE REVIEWS Volume: 215 Issue: 1 DOI: 10.1007/s11214-018-0574-6, 2019.