Iceland Liechtenstein Norway grants

Programme Kappa

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Acronym: NASPMON

NAtural Seismicity as a Prospecting and MONitoring tool for geothermal energy extraction

Supplement of V11: Improvement of routine seismic monitoring

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Supplement of V11: Improvement of routine seismic monitoring

A quality check and performance comparison has been performed using the PEPIN, SeisComP and QuakeMigrate software during a very seismically active period, the 2022 magmatic dyke intrusion. All software provides good and robust automatic earthquake locations, nevertheless there is room for even more tuning of the algorithms. There is a tradeoff between computational time and the level of improvement, so it needs to be carefully evaluated. The three phase pickers we tested are all performing well, improved automatic locations facilitate manual polarity picking of earthquakes. All three algorithms, PEPIN, SeisComp and QuakeMigrate can easily be run with all available stations in the area which can even further assist with manual polarity picking. Even so, we strive to take this further and test automatic polarity picking within the timespan of the project.

The SeisComP PEPIN and QuakeMigrate detection and location algorithms have were fine-tuned . While SeisComP itself is not a location algorithm, the results obtained using SeisComP will be referred to as the SeisComP results. The actual location algorithm used by SeisComP in this study is *scanloc*, a commercial module from Gempa, the maintainers of SeisComP. QuakeMigrate is a migration-based detection and location algorithm and therefore inherently different from the other two pick-based methods. QuakeMigrate is currently running in real-time on the Reykjanes Peninsula part of the SeisComP system at ÍSOR, in a test-phase before being integrated into the routine monitoring system. ÍSOR is in the process of processing all the seismic data using QuakeMigrate from 2022 backwards to 2013, but this is computationally expensive and has taken longer than expected. In order to speed up the process, we have finally secured more CPUs since December 2022, acquiring additional 32 CPU on an internal server in addition to the 24 CPU in use for the NASPMON project.

The PEPIN (IG and CU derived) and SeisComP (ÍSOR derived) catalogues for the whole period of the REYKJANET network operation, 2013-2022, are ready and available to all participants in the project. The PEPIN catalogue consists of ~180,000 automatic events, ~53,000 high quality events that full fill the criteria RMS<0.15s and minimum 6 stations picked (Fig. 1). The SeisComp catalogue consist of ~270,000 events while all earthquakes of quality parameter Q > 0.95 are shown in Fig. 2 , a total of ~122,000 events. The SeisComP results are evaluated using a random forest classifier to assess the quality of events in the automatic catalogue. The model evaluates the earthquake solution, and outputs a classification score ranging from 0.0 to 1.0. In general, a classification score below 0.5 means the event is discarded as noise. This leaves confirmed events of varying quality in the range of 0.5 to 1.0.

The ÍSOR derived QuakeMigrate catalogue is still not complete, for the whole period of the REYKJANET network operation, due to computational issues. The final catalogue should be ready in the first quarter of 2023. Nevertheless, the results are promising. Fig. 3 compares outputs from the three software, during an intense period of seismicity, where events are tightly spaced in time, accompanying the 30 July – 3 August 2022 dyke intrusion. The input into the software is comparable, the raw data,

the same velocity model and similar station configurations. QuakeMigrate locates a slightly higher number of earthquakes (10,112), and it has the clearest spatial distribution, where structures are visible. PEPIN and SeisComP both do very well, locating 9,966 and 10,0087 events, respectively. This comparison is important for each respective institution and is a good quality check on our methodology.

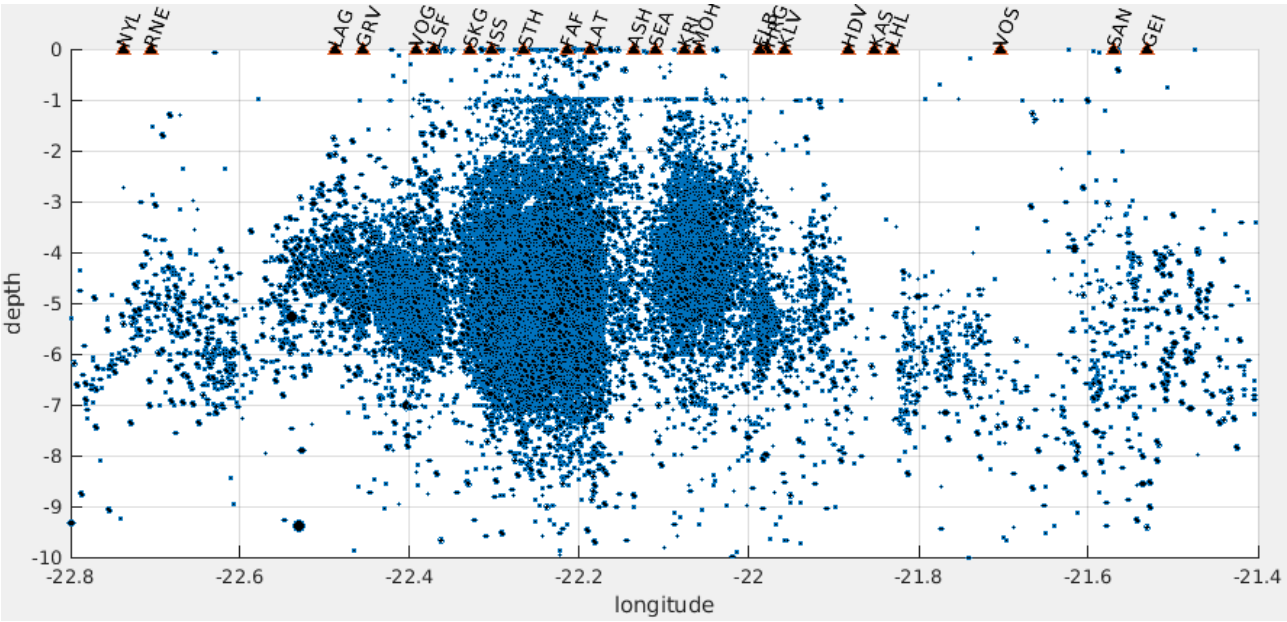

Fig. 1. *Longitude-depth cross-section of earthquake locations from 09/2013 to 12/2022 calculated by PEPIN software. In total over 180,000 events were detected, here we show only a subset with high-quality location (~53,000 events).*

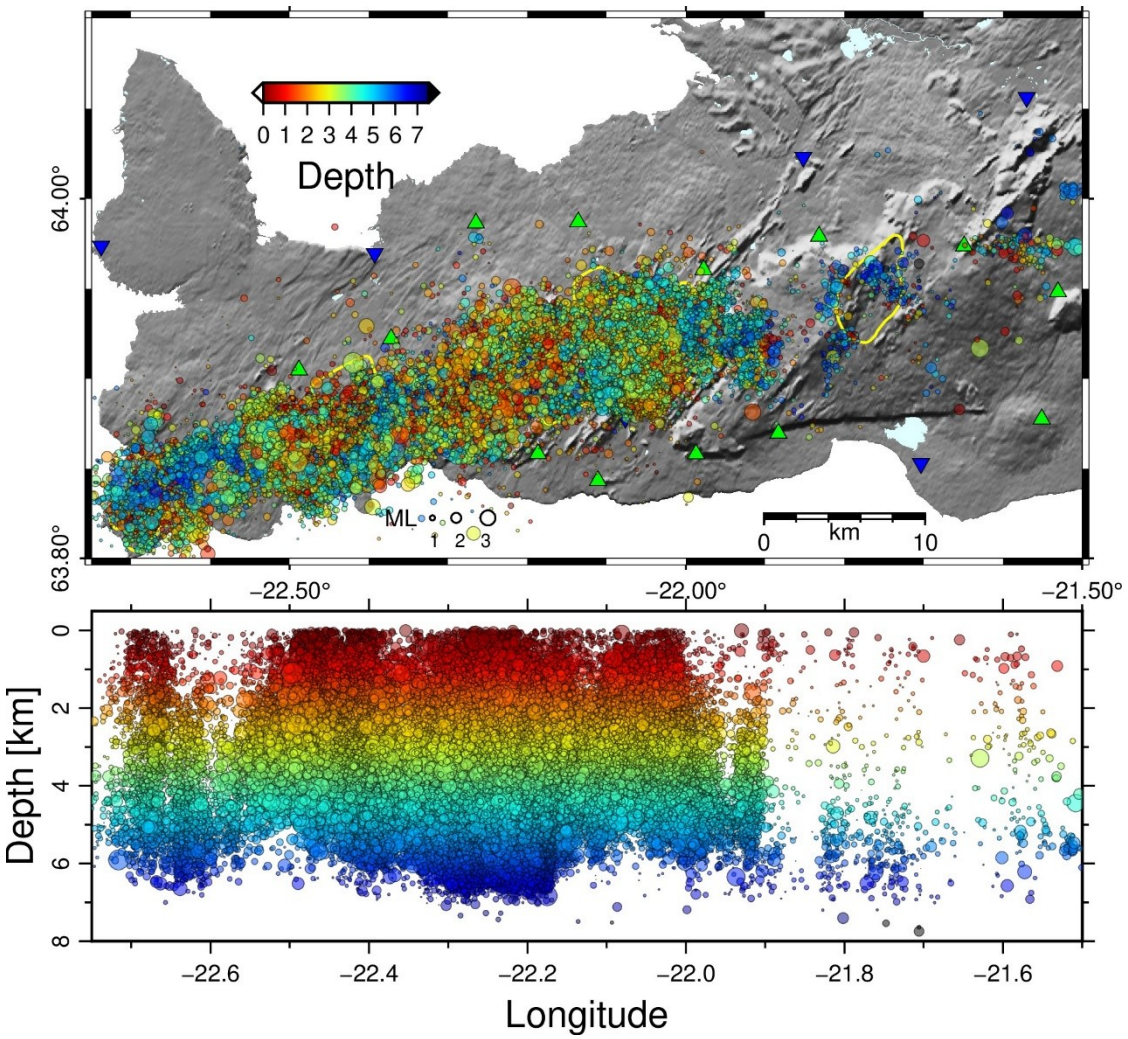

Fig. 2. *A map of SeisComP earthquake locations from 2013 to 2022, showing a total of ~122,000 automatic events of Q > 0.95, and the corresponding depth section from surface down to 8 km depth. Earthquake locations are colored according to depth.*

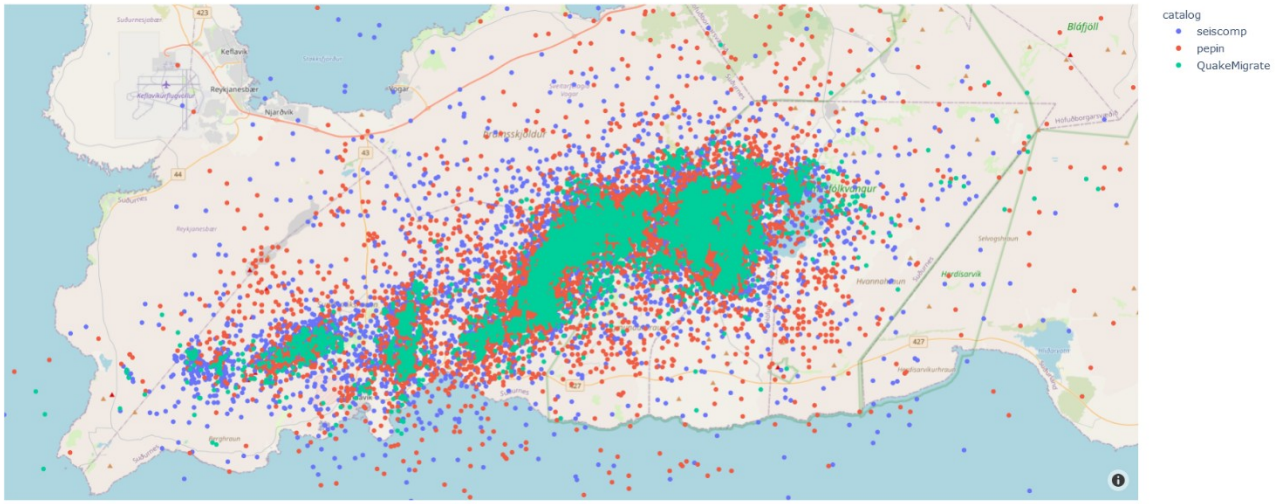

Fig. 3. *Automatic earthquake locations from three different detection and location algorithms for the time period 30 July – 3 August 2022. SeisComP locations are shown in blue, 10,0087 events, PEPIN locations are red, 9,966 events and QuakeMigrate locations are green, 10,112 events. Note that in this figure none of the catalogs have been pruned of low-quality events.*

To the first order PEPIN and SeisComP results are comparable – QM seems more detailed. All catalogs are presented as they are delivered from their respective tools without quality assessment. Removing events of low quality reduces the spread in spatial distribution considerably. It is notable however that the QM catalog has a very similar number of events, but all of them are clustered around the tectonic features of the area.

In order to make a meaningful comparison of the three algorithms in detail of phase picking, we chose on of the most intense periods of seismicity during the 2022 dyke propagation (Fig. 3).

We show here a subset of 30 min. of data to work with on 31 July, i.e., 20:30-21:00. Plotting raw waveforms with automatic pics from each respective earthquake location method. During the period PEPIN locates 62 events, SeisComP 64 and QuakeMigrate 65 events (Fig. 5). All algorithms are capable of the correct association of P- and S-phases. Fig. 4 shows a QuakeMigrate automatic pick example from station ELB, showing the association of the P- and S-phase pick.

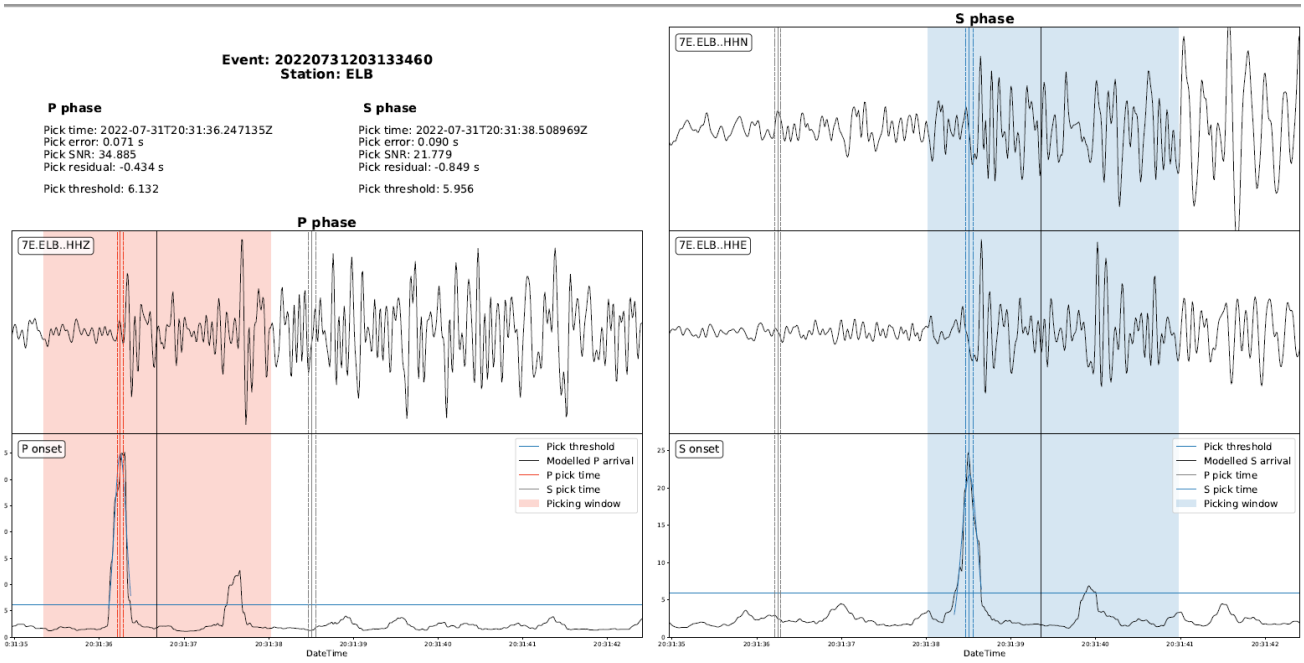

Fig. 4. *An automatic QuakeMigrate pick example from REYKJANET station ELB, showing the association of the P- and S-phase pick.*

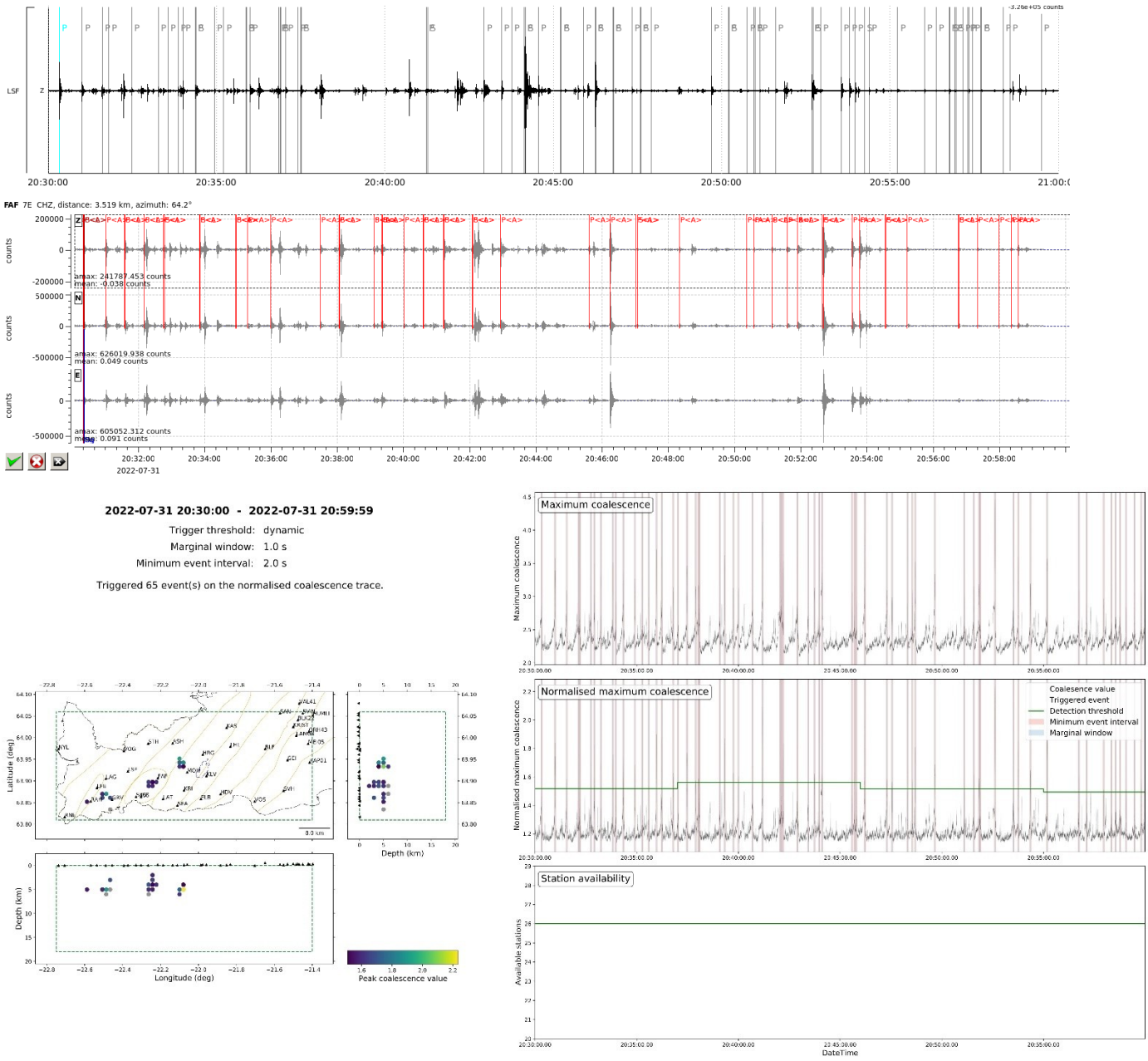

Fig. 5. *A subset of 30 min. of data from the 31st of July 2022, plotting raw waveforms with automatic picks from each respective earthquake location method. Top: PEPIN (62 events). Middle: SeisComP (64 events). Bottom: QuakeMigrate (65 events).*

Results obtained from PEPIN, SeisComP and QuakeMigrate are comparable (Fig. 3 and Fig. 5), which is reassuring and interesting given the different methodological approaches. Nevertheless, there is scope for even better tuning of the algorithms given that some events are missed (Fig. 5)