Recent microseismicity observed at Hekla volcano and first velocity inversion results

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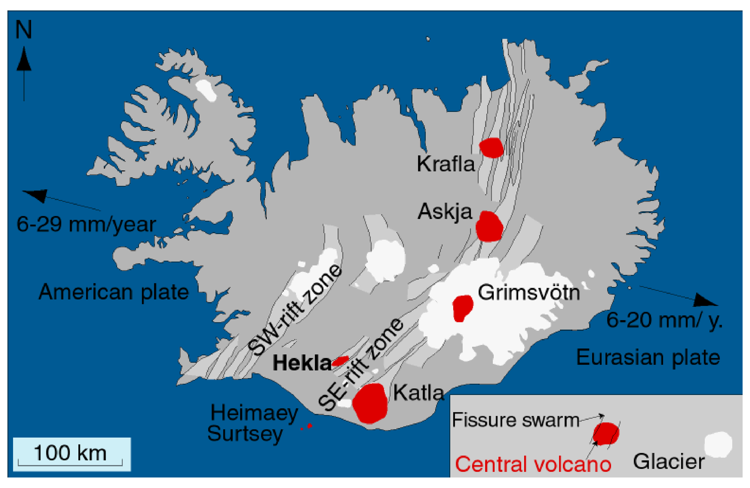
1. Introduction

- Hekla volcano in Iceland presents a high hazard to local infrastructure, air travel and a growing tourist population.
- In 2018 we installed the real-time seismic network HERSK directly on Hekla's edifice in order to
  1.) better our understanding of the processes driving the evolution of pre-eruptive seismicity
  2.) improve pre-eruption warning time which previously was around 1 hour

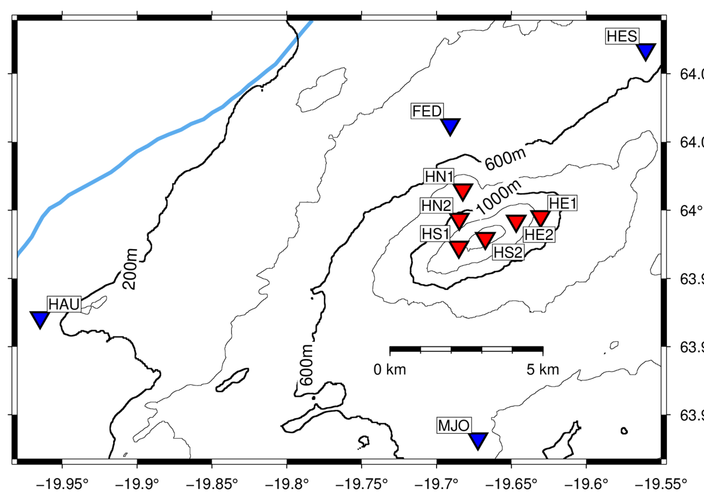


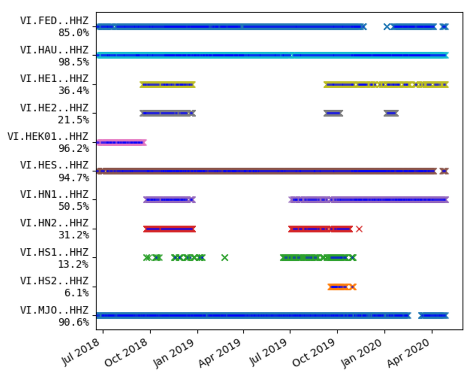
from http://www.decadevolcano.net

- We derive a velocity model from observed microseismicity:
  1.) to be employed for a real-time detection/location system that we are developing
  2.) used as input for a 3D tomography inversion
- We observe microseismicity swarms that occur in freezing conditions, probably related to expansion of fluid filled crevices.

2. HERSK, the Hekla Real-time Seismic Network

- The six HERSK stations were deployed within 2.5km from the summit, see red markers in map to the right.
- We also use data from 4 nearby stations operated by IMO as part of their national network, see blue markers.

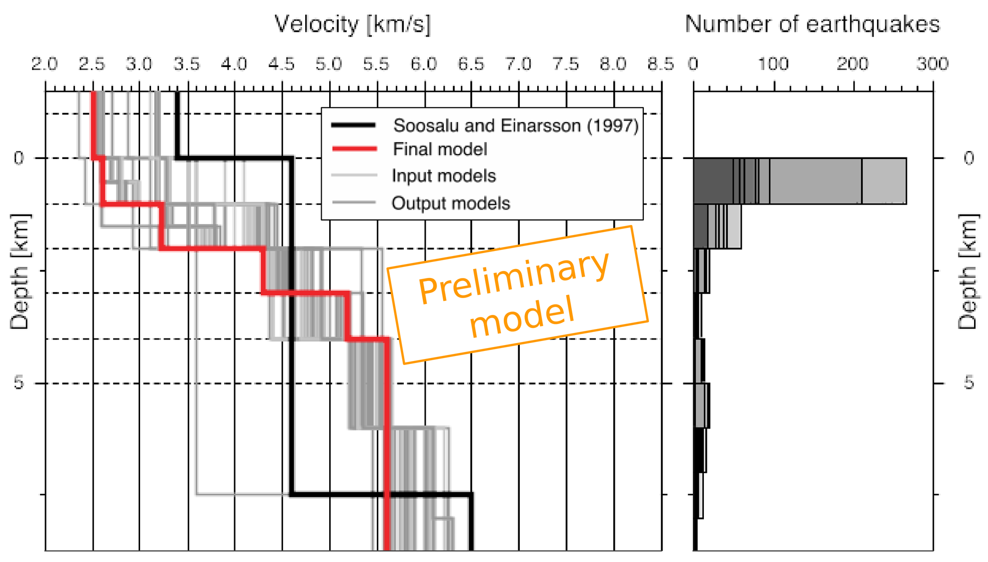




- The stations and their 3G routers are powered with wind generators and solar panels.
- Data outages are common due to extreme icing on Hekla, especially during the first half of each year, see data completeness plot to the left.

3. 1D p-velocity inversion

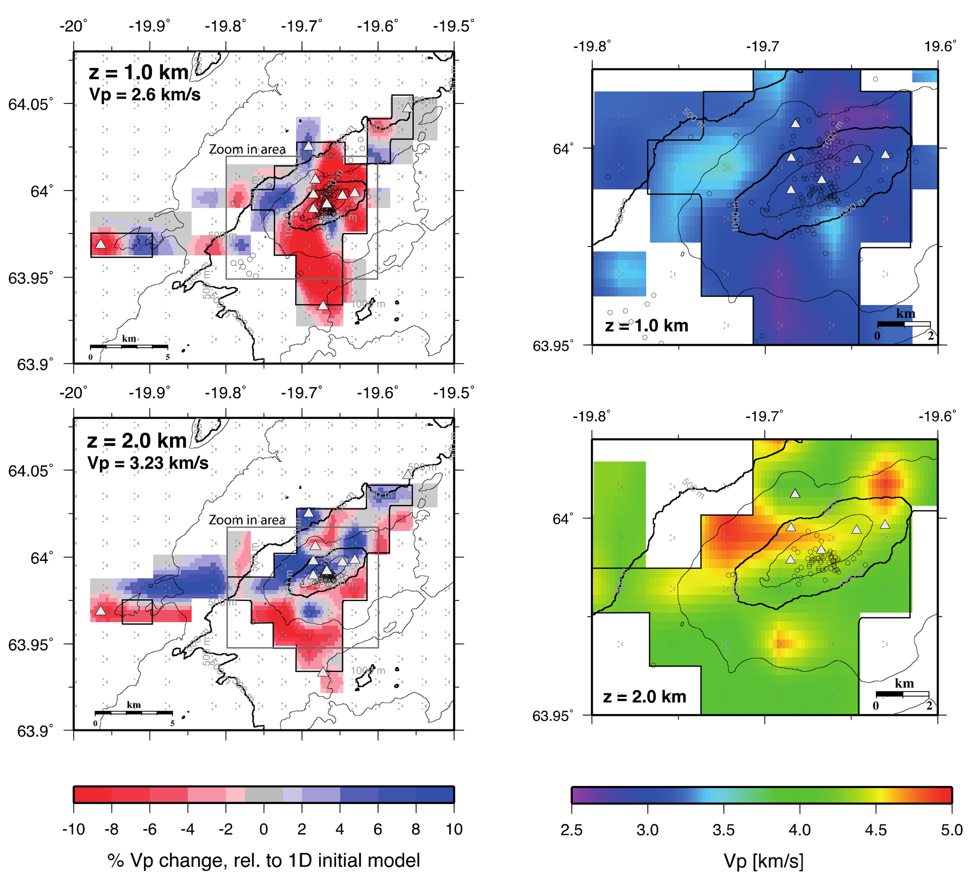
- Inversion for best-fitting p-velocity model using VELEST code from Kissling et al. (1994)
- Starting model by Soosalu and Einarsson (1997), see black line in figure to the right. It is an average model based on a collection of refraction profiles in the South Iceland region
- Considering local events detected with scanloc Seiscomp3 module, azimuthal gap < 180, nobs ≥ 5

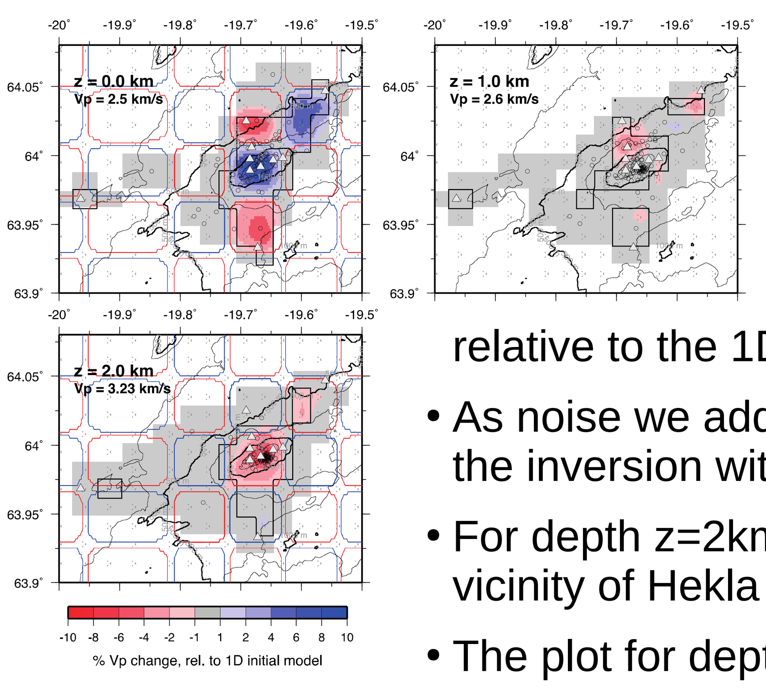


- Series of iterative inversions using different initial models, see grey lines
- Each resulting velocity model (dark grey lines) is checked and if necessary data cleaned before updating model for next inversion
- Our **preliminary** 1D velocity model for Hekla is shown as a red line

4. 3D tomography

- Figures to the right show 3D p-velocity structures obtained with simultaneous inversion code SIMULPS14, extended by a full 3-D ray shooting technique (Haslinger and Kissling, 2001)
- Results from 1D inversion used as input: cleaned phase picks and final 1D p-velocity model
- Model resolution is 2.5km horizontally and vertically the same as in the 1D velocity model
- Inverted velocity structures, see figures to right, are in agreement with NE-SW geological trend due to rift

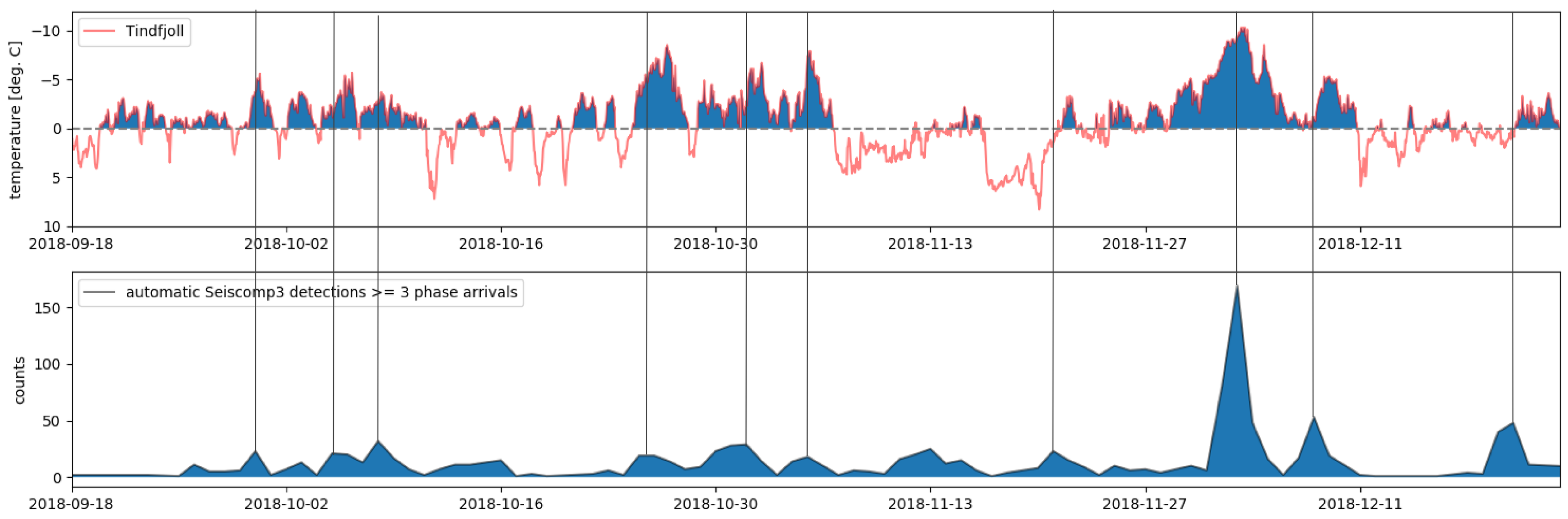




- Figures to the left show results of a synthetic checkerboard data test
- For depths of 0km and 2km we introduced high and low velocity anomalies with ± 10% change relative to the 1D initial model, see red and blue squares
- As noise we added Gaussian errors of 0.05 s to the data and run the inversion with same parameters as the real data
- For depth z=2km a reliable resolution is only achieved in the direct vicinity of Hekla volcano
- The plot for depth z=1km shows that "vertical leakage" is small

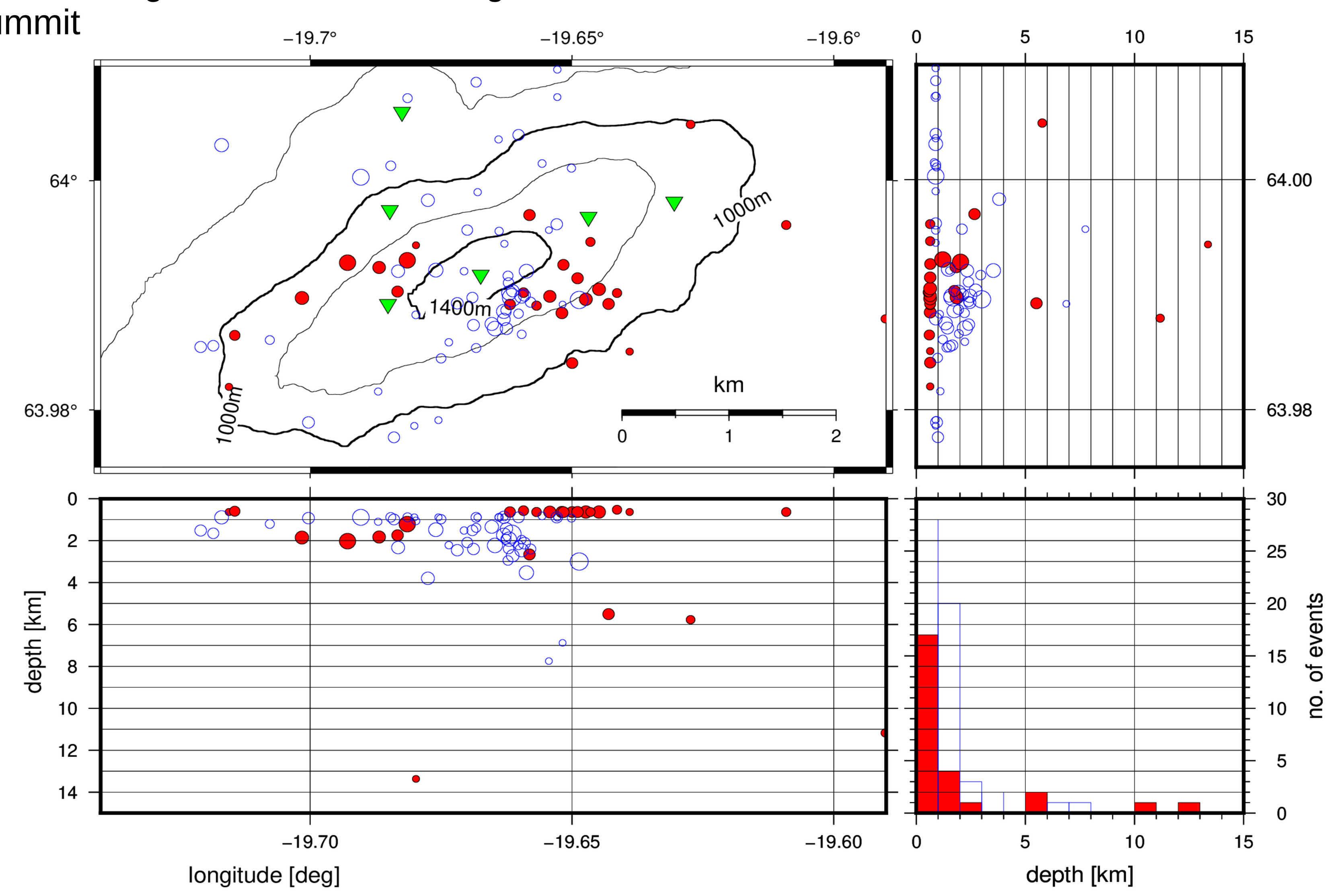
5. Seismicity related to freezing temperatures in autumn 2018

- On the 3rd December 2018 more than 150 micro-earthquakes were detected at Hekla, see graph below.
- The number of events detected with the Seiscomp3 scanloc module correlates with temperature data (Icelandic Meteorological Office, 2019) from the Tindfjöll mountain range near Hekla, see graph below.
- Peaks in the number of detected micro-earthquakes sometimes occur before a negative temperature peak is reached.
- The observed microseismicity is probably related to expansion of fluid-filled crevices located in the ice field on the northern flank of Hekla or in the shallow sub-surface of Hekla itself.



6. Seismicity observed in autumn 2018

- Event locations for the time period 23rd September to 22nd December 2018 are shown in the map below. This time period coincides with maximum HERSK station data availability in 2018, see data completeness plot in left half of this poster
- Event locations marked in red are from the IMO catalogue, event locations in blue are obtained from the VELEST 1D velocity inversion
- Both catalogues show a clustering of events within ~1km to the southeast from Hekla summit



7. Summary

- We present a new 1D velocity model for Hekla volcano. It is well constrained for depths to about 8km below sea level and we obtain a velocity of 2.5 km/s for the 1st layer in the model from the summit (~1,500m) down to sea level.
- We present the first 3D velocity tomography results for Hekla volcano. The obtained structures are consistent with the NE-SW topography trend caused by the volcanic activity and it could be related to magma structure underneath the volcano.
- We observe microseismic activity related to freezing events. Occurrences of such swarms could possibly mask micro-seismicity related to volcanic activity.

8. Outlook

- Locate events with NonLinLoc to take topography into account
- Implement a real-time Seiscomp3 installation with NonLinLoc locator
- Use other methods to locate events with low phase count < 5
- Obtain shallow velocity structure using correlation of ambient seismic noise

Acknowledgement and References

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