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High Resolution Seismic Velocity Structure of Makushin Volcano, Alaska

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Introduction

Makushin Volcano is located in the eastern portion of the Alaska-Aleutian subduction zone. It is among the most active volcanoes in the United States and has been classified as high threat based on eruptive history and proximity to the City of Unalaska and international air routes. In 2015-2016, we supplemented the one-sided station coverage provided by the Alaska Volcano Observatory (AVO) permanent seismic network with a set of five individual stations and three mini seismic arrays of 15 stations each.

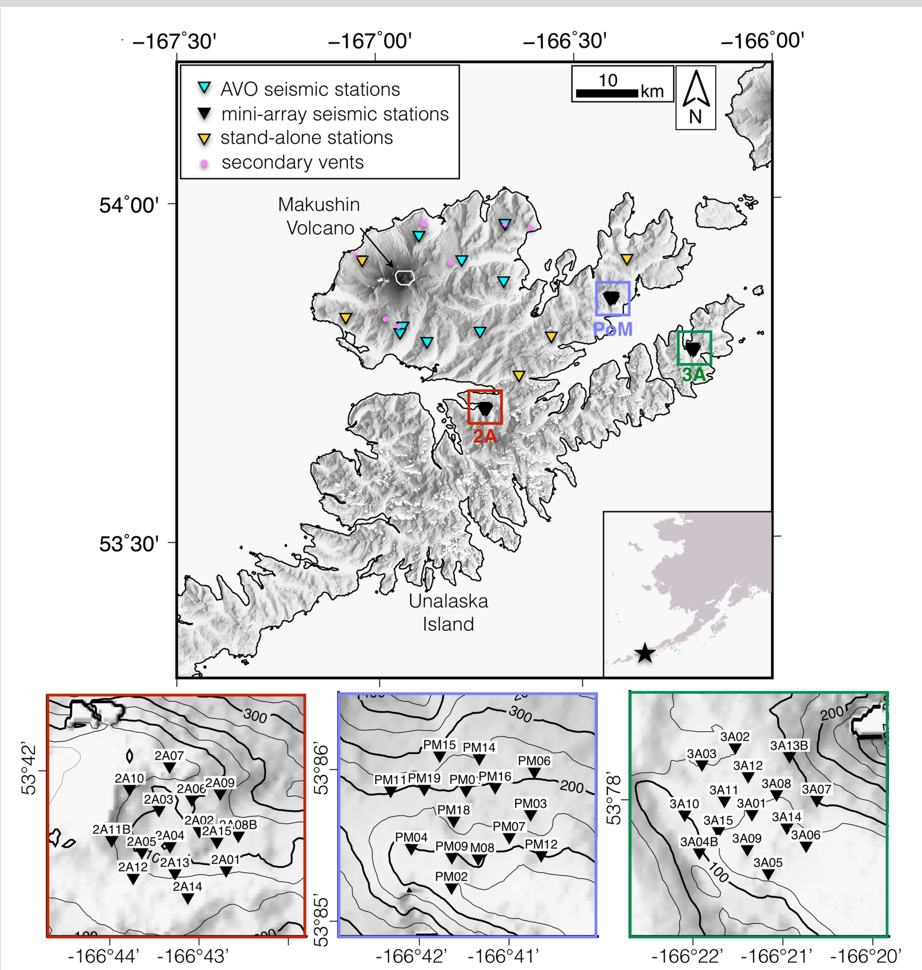


Fig. 1. Map of station coverage for Makushin Volcano. The additional stations from the 2015-2016 deployment provide us with a better azimuthal coverage.

Data and Methods

- Seismic data used in this study consists of 21,712 P and 11,712 S arrivals of local earthquakes from 1996 to 2016. The earthquake catalogue includes AVO station picks and automatically generated picks for the additional temporary networks. We used the new autopicking software package REST by S. Roecker (2017) to estimate onsets of P and S phases, and initial event locations.
- The starting velocity model is based on the inverted 1-D model from Syracuse et al. (2015)
- Inversion for body wave velocity structure and earthquake location is carried out using SIMULPS14T (Thurber, 1983; Eberthart-Phillips, 1990; Evans et al., 1994) with a pseudo-bending ray tracer.

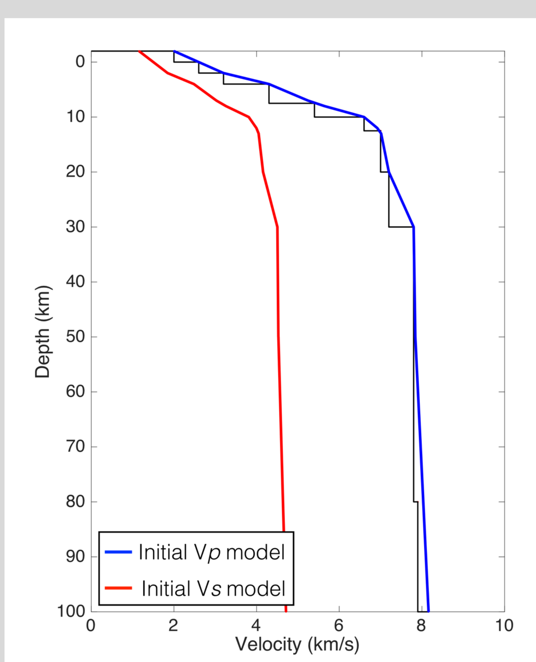


Fig. 2. Initial 1-D Vp and Vs models used for the inversion. These are obtained from a 1-D inversion of a preliminary version of our dataset starting with an initial 1-D model from Syracuse et al. (2015). It assumes Vp/Vs=1.78

Results

1. Hypocenters Selection

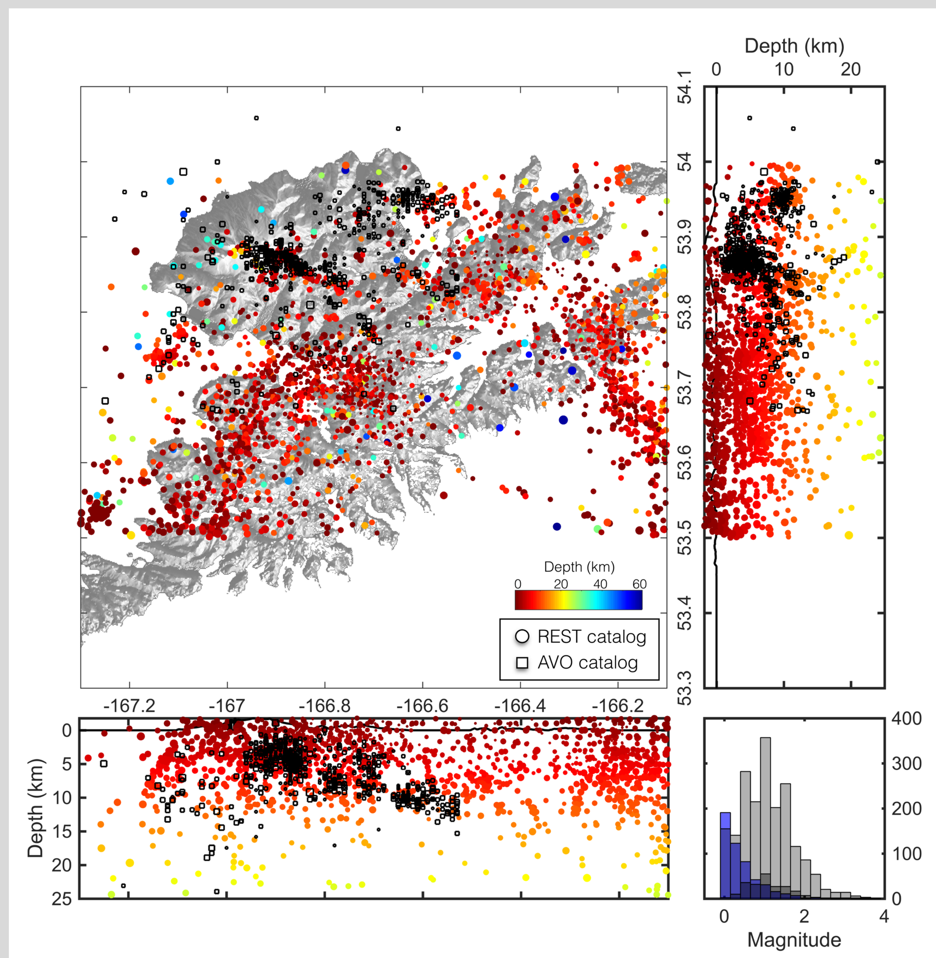


Fig. 3. REST Initial locations of 2430 earthquakes from Jul-2015 to Jan-2016. Event detection is highly improved with the presence of the augmented network. Symbol size is proportional to event magnitude. Colors refer to depth. The black squares represent the events in the AVO catalog for the same period of time.

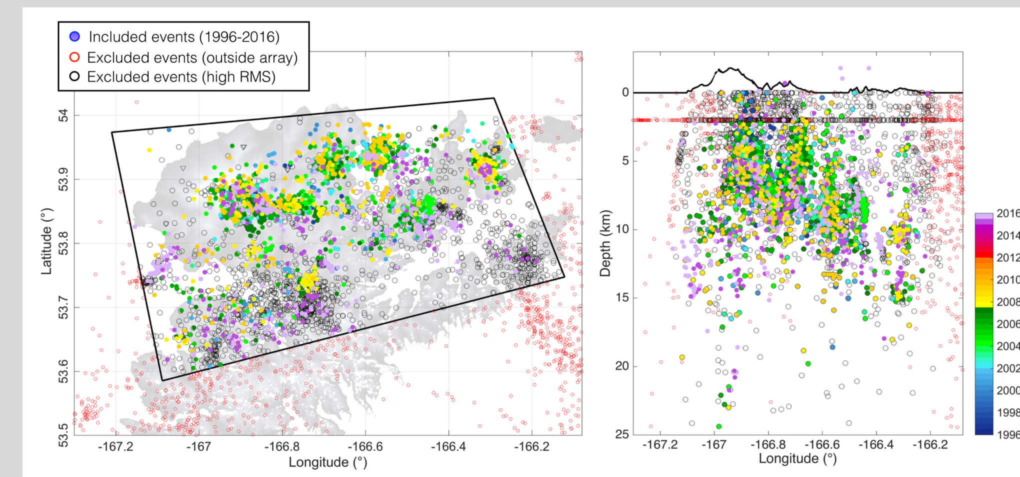


Fig 4. Events selection based on initial location, and RMS quality. The colored circles represent the final 2196 events used in the inversion. Colors refers to the year of occurrence.

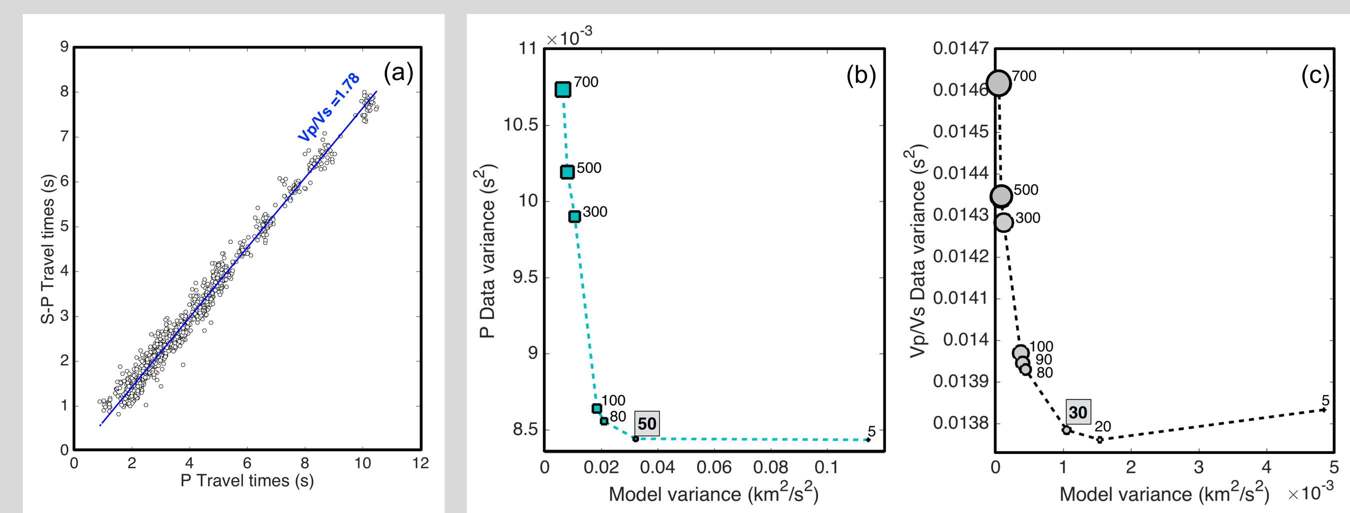
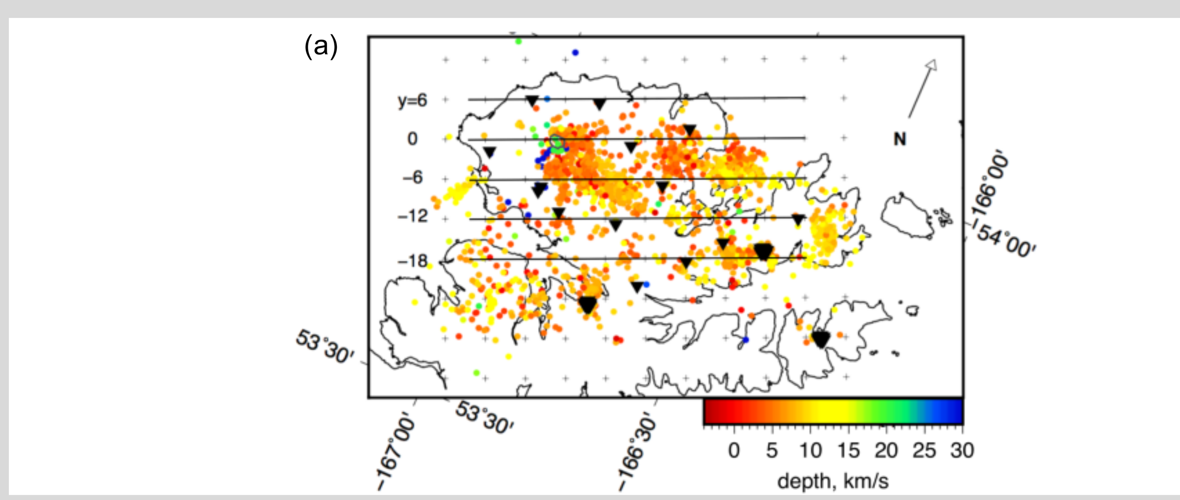
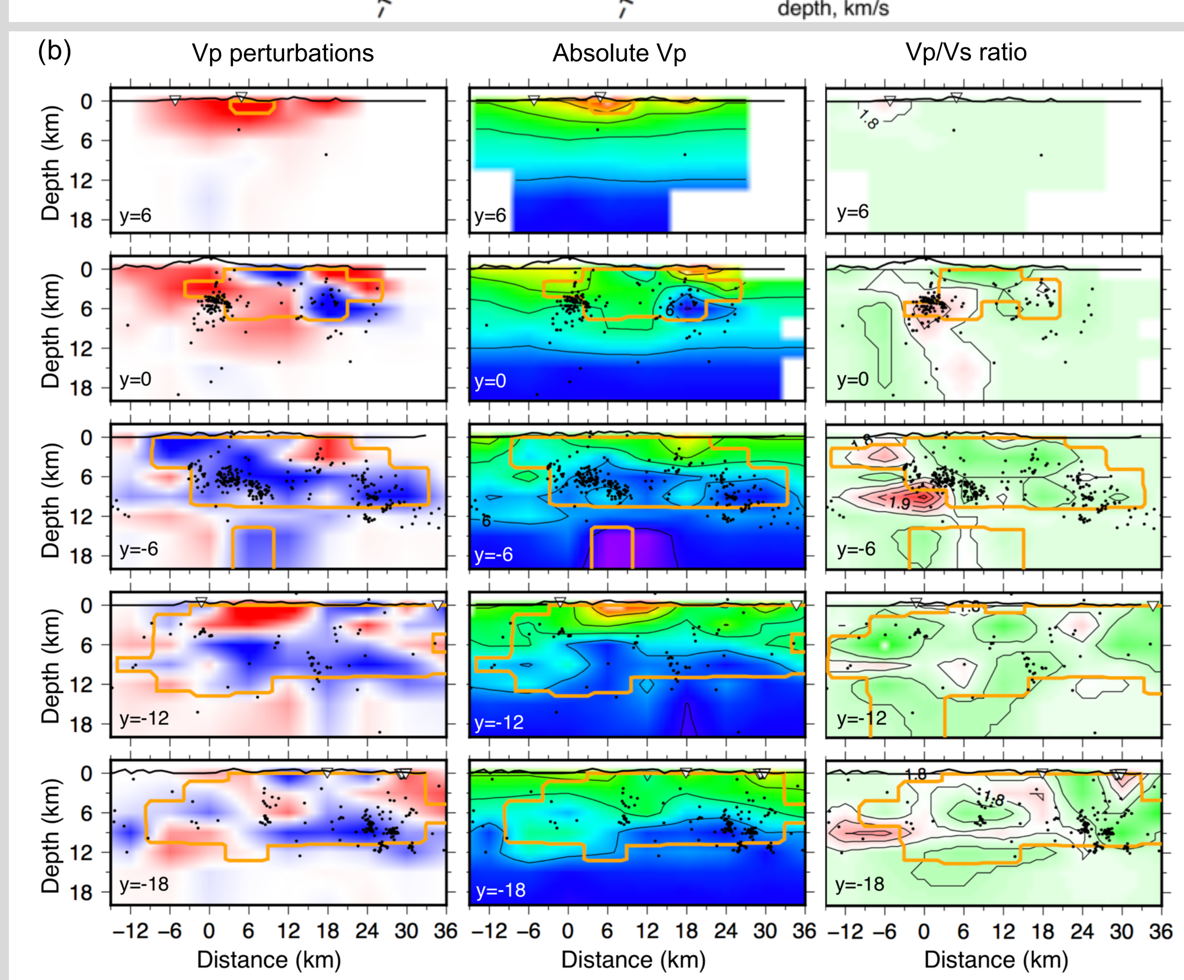


Fig 5. (a) Wadati diagram. The line fit provides an average Vp/Vs ratio of 1.78. Trade off curve for (b) Vp and (c) Vp/Vs to determine optimal damping values. The appropriate damping factors are 50 for Vp and 30 for Vp/Vs.

2. Velocities

- High-Vp areas are focused partially beneath the caldera and underneath several secondary vents
- High Vp/Vs regions are found at ~6 to 12 km





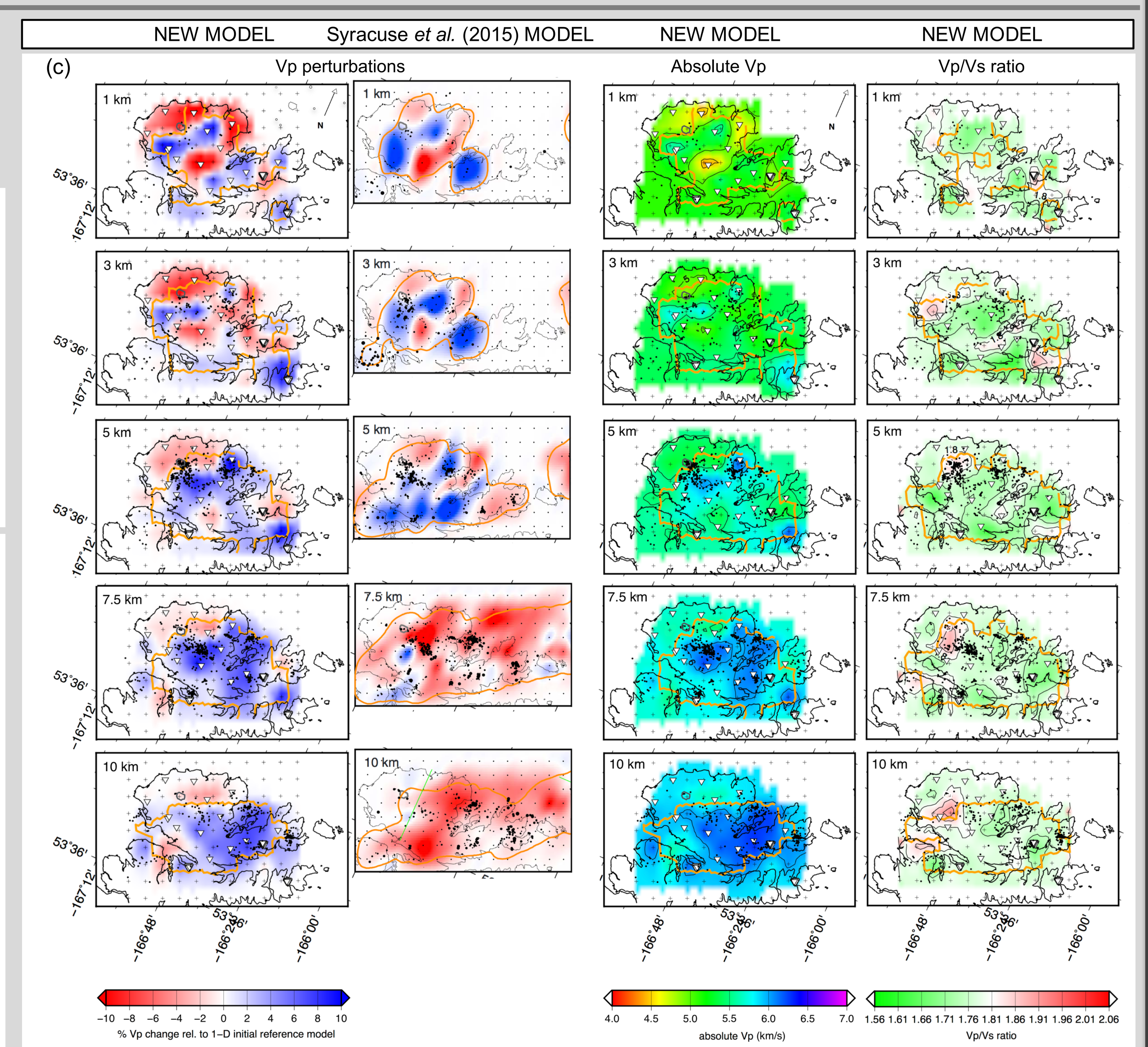
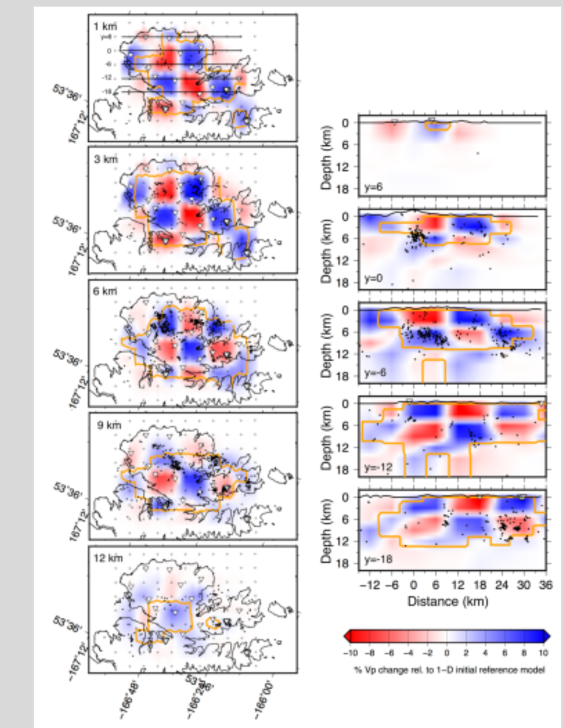


Fig. 6. Relocations of 2196 earthquakes (a) in map view, (b) in cross sections, and (c) in depth slices through the final 3-D Vp model, shown as perturbations to the initial model as well as absolute Vp and Vp/Vs ratio. In (c) we compare our results (left panel) with the tomographic model of Syracuse et al. 2015 (right panel). Orange contours indicate resolution matrix = 0.1.

3. Velocity Recovery

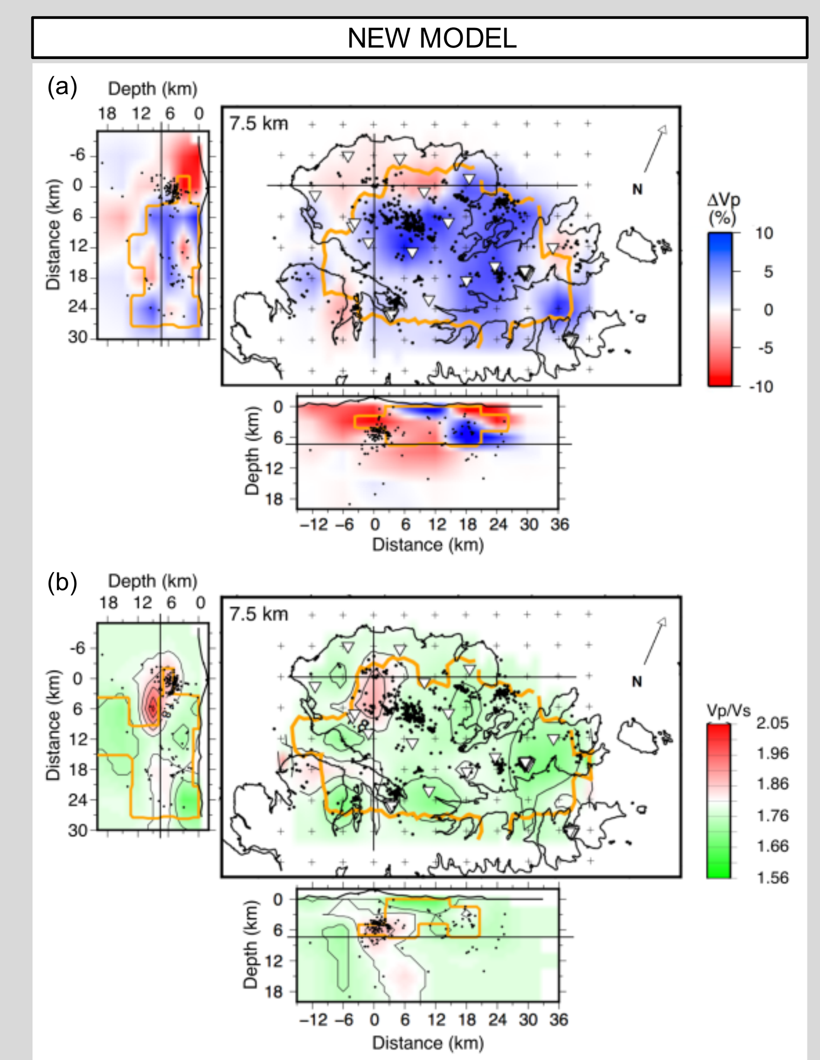


Checkerboard test results for Vp initial perturbations of ± 1 km/s that spans two nodes in each horizontal direction. Vp/Vs is held constant in the input model. We observed that the checkerboard pattern is well resolved in the area containing most of the crossing rays down to a depth of ~9 km.

Fig. 7. Depth slices and cross-sections of the checkerboard recovery. Diagonal element of the resolution matrix contour at 0.1 is shown in orange.

Discussion and On going work

The upper 5 km high-Vp areas are possibly delineating remnant magma pathways. Low-Vp regions observed at ~6 to 10 km in Syracuse et al. (2015) are not as well defined in our results. This region, however, is shown to have high Vp/Vs ratio in our model, and it may be related to a region of longer-term storage, as geodetic models seem also to indicate (Lu and Dzurisin, 2014).



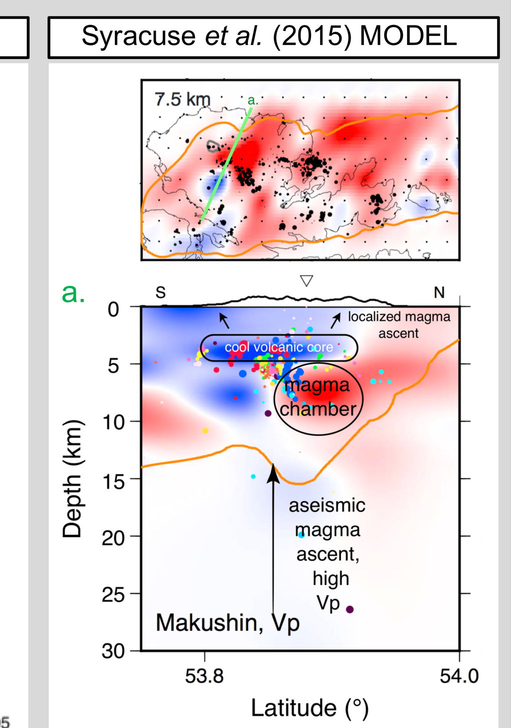


Fig. 9. 7.5 km depth slice and N-S cross section and interpretation of Makushin magmatic system based on previous tomographic study by *Syracuse et al. (2015)*

Fig. 8. 7.5 km depth slices and cross-sections at Makushin volcano summit for Vp perturbations (a) and Vp/Vs ratio (b) from this study.

On going work includes:

- Ambient noise tomography to ultimately obtain a 3D Vs image
- Joint inversion of body and surface wave

Data and Resources

The instruments used in the field were provided by the Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) facility of the Incorporated research Institutions for Seismology (IRIS). Data collected during this experiment will be available through the IRIS Data Management Center.

Acknowledgments

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