Seismic Velocity Changes below the Great Sitkin Volcano in Central Aleutian Islands Associated with Recent Eruptive Activities

Cody Kupres[1,2] and Xiaotao Yang[1,2]

[1]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University
[2]Purdue University

November 30, 2022

Abstract

Volcanic eruptions are potentially hazardous natural events. Understanding how magma accumulates, migrates, and erupts is important to understanding and, eventually, predicting volcanic eruptions. However, the variation in the scale of volcanoes, co-occurrence of earthquakes, and the duration of the eruption makes understanding these events difficult. Ambient noise interferometry is becoming an increasingly more popular tool to study and monitor active volcanoes. We use this method to characterize the variations of subsurface seismic velocities associated with different stages of the eruption process at the Great Sitkin Volcano in the central Aleutian volcanic arc. This volcano initially erupted in May 2021 with elevated seismicity and gas release, followed by the formation of a new lava dome starting July 2021. The volcano had an increase in seismicity in February 2020 but without any eruption activity reported. Measuring the variation of seismic velocities from August 2019 to March 2022, we observe a local decrease in velocity leading up to the eruption and an increase in velocity following the emplacement of the lava dome. We do not observe any velocity variations preceding the non-eruptive increase of seismic activity in February 2020. Despite its remote location and relatively small scale, the findings of this study at the Great Sitkin volcano have significant implications for understanding volcanism and the development and prediction of volcanic eruptions in general.

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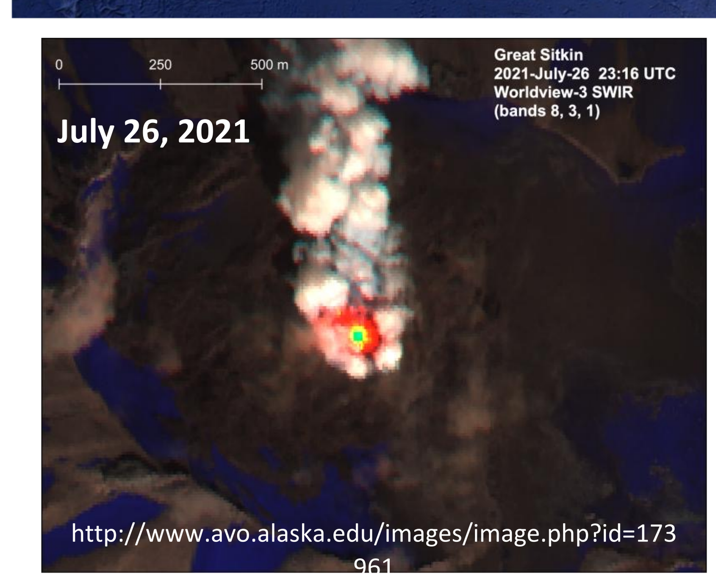
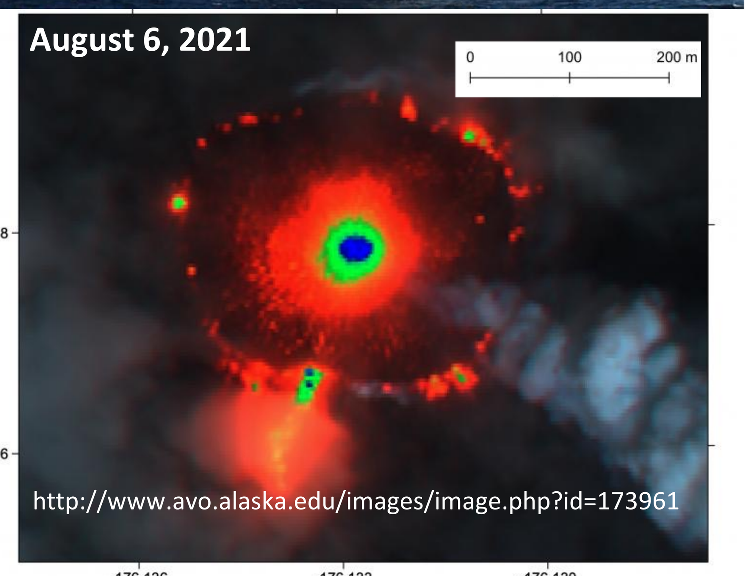
1. Introduction

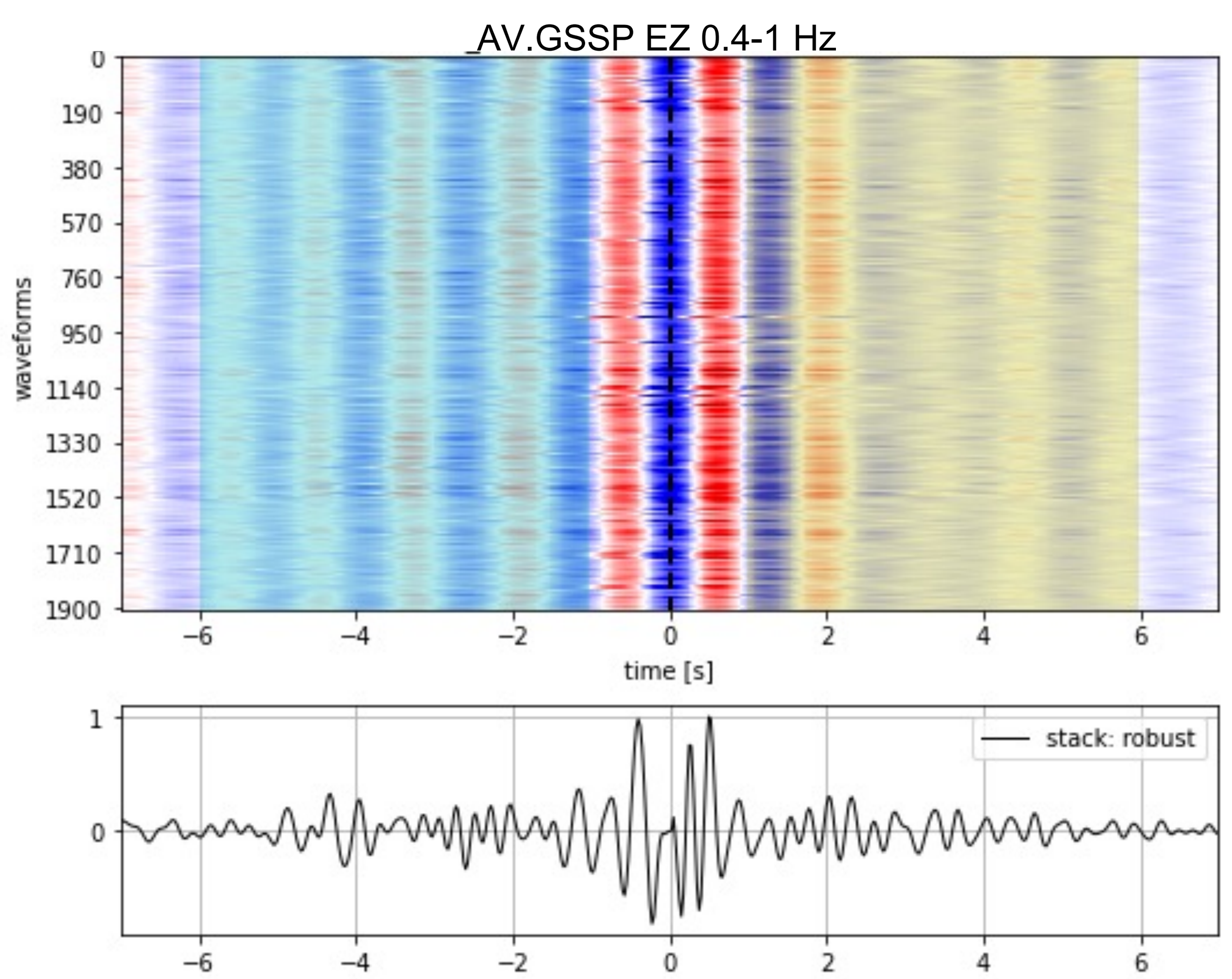
Magmatic processes beneath active volcanoes can be characterized by analyzing changes in seismic velocity. We aim to identify these magmatic processes with observations from multiple datasets to delineate the complicated eruption of the Great Sitkin Volcano. The GS Volcano explosively erupted on May 26th, 2021. This was followed by increased seismicity at the crater and the formation of a new lava dome in July and August of 2021 with effusive eruptions continuing present day.





2. Methods

The changes in seismic velocities are measured from 2-hour seismic noise cross-correlation functions and use trace stretching to maximize correlation. The time shift between the reference trace and the current noise correlation function is used to determine the temporal change in seismic velocity. The reference trace used is from June 2019 to February 2020, the data's most seismically quiet period. The dv/v was measured using 12-hour stacks with a window length of 5 seconds, offset by 1 second. The figure below displays the correlation data overlaid with the dv/v measurement window (cyan/yellow). The bottom plot is the reference trace.

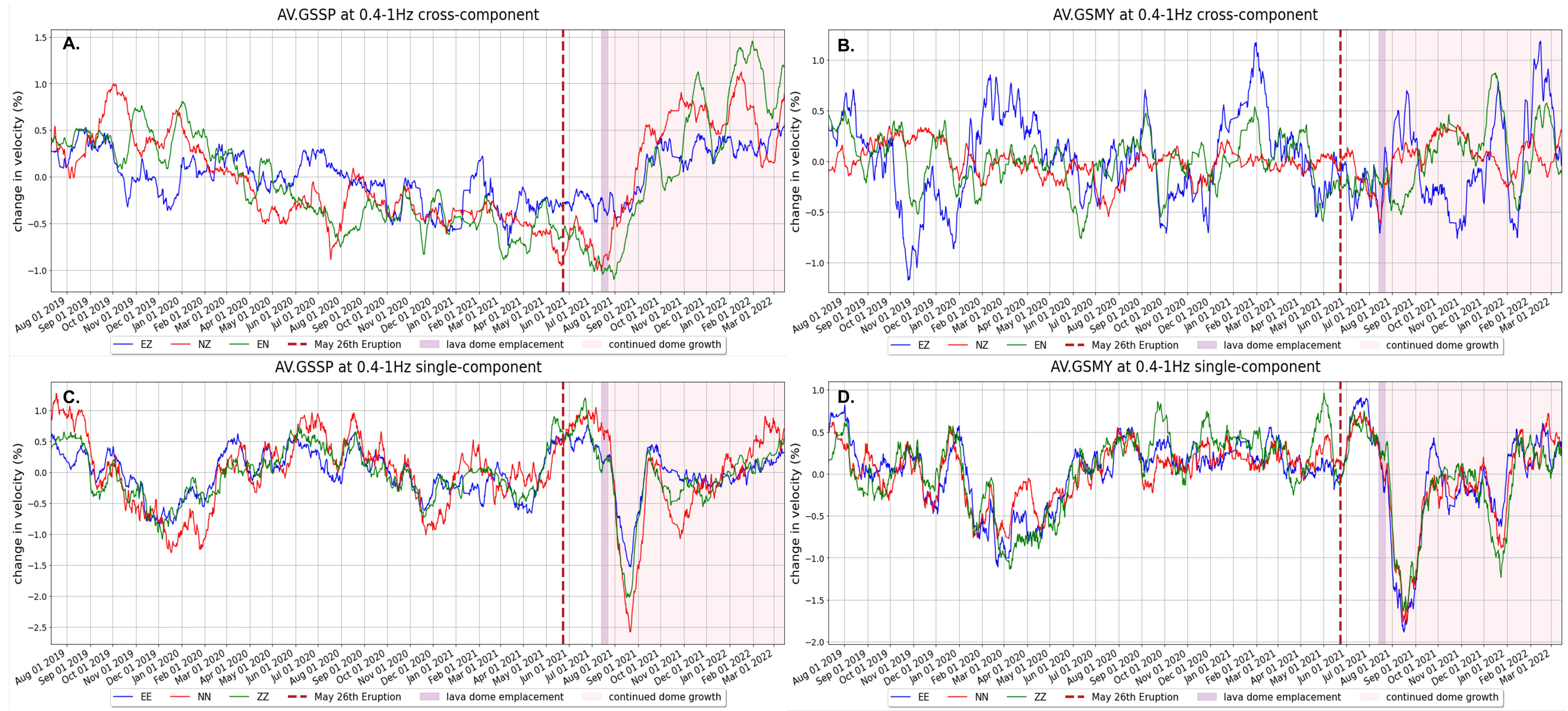


3. Temporal velocity changes

Panels to the right show the calculated changes in seismic velocity from three-component stations GSSP and GSMY. Cross-component and single-component data was computed for both stations. Data was averaged by a 20-Day moving window mean.

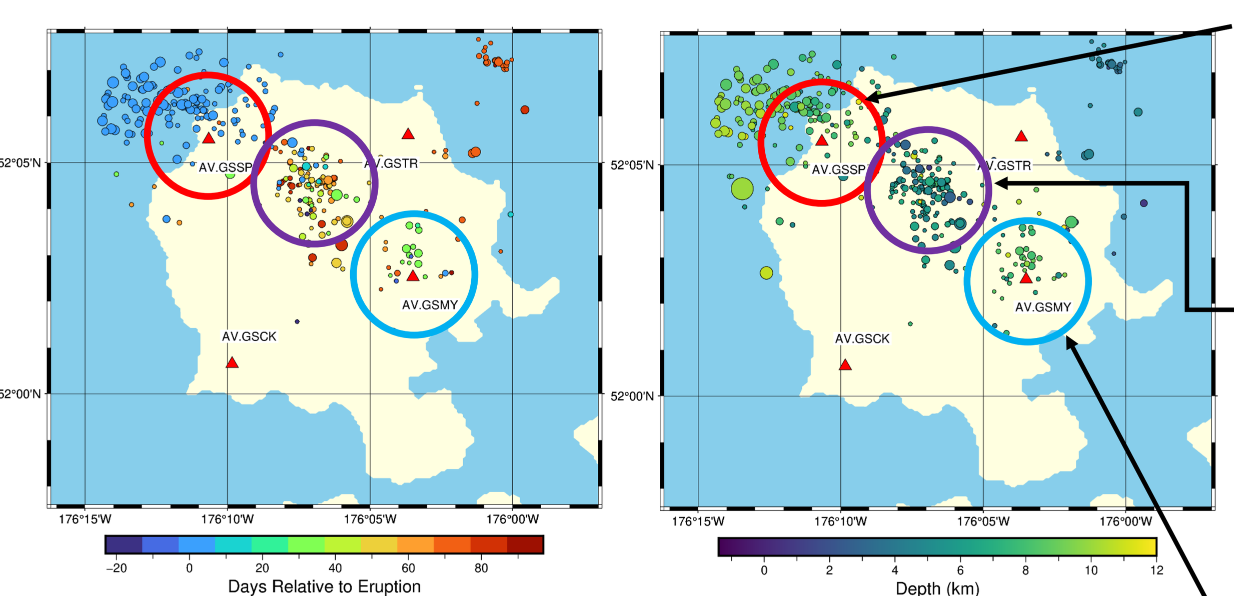
Key Observations:

- ***Located NW of the crater, cross-component AV.GSSP displays long-term (> 1.5 years) decrease in velocity, followed by increasing velocity starting August 2021 (Panel A).***
- ***All stations show a stark decrease in velocity (up to 2.5%) for single-component measurements in August 2021, followed by an increase in September 2021 (Panels C-D).***



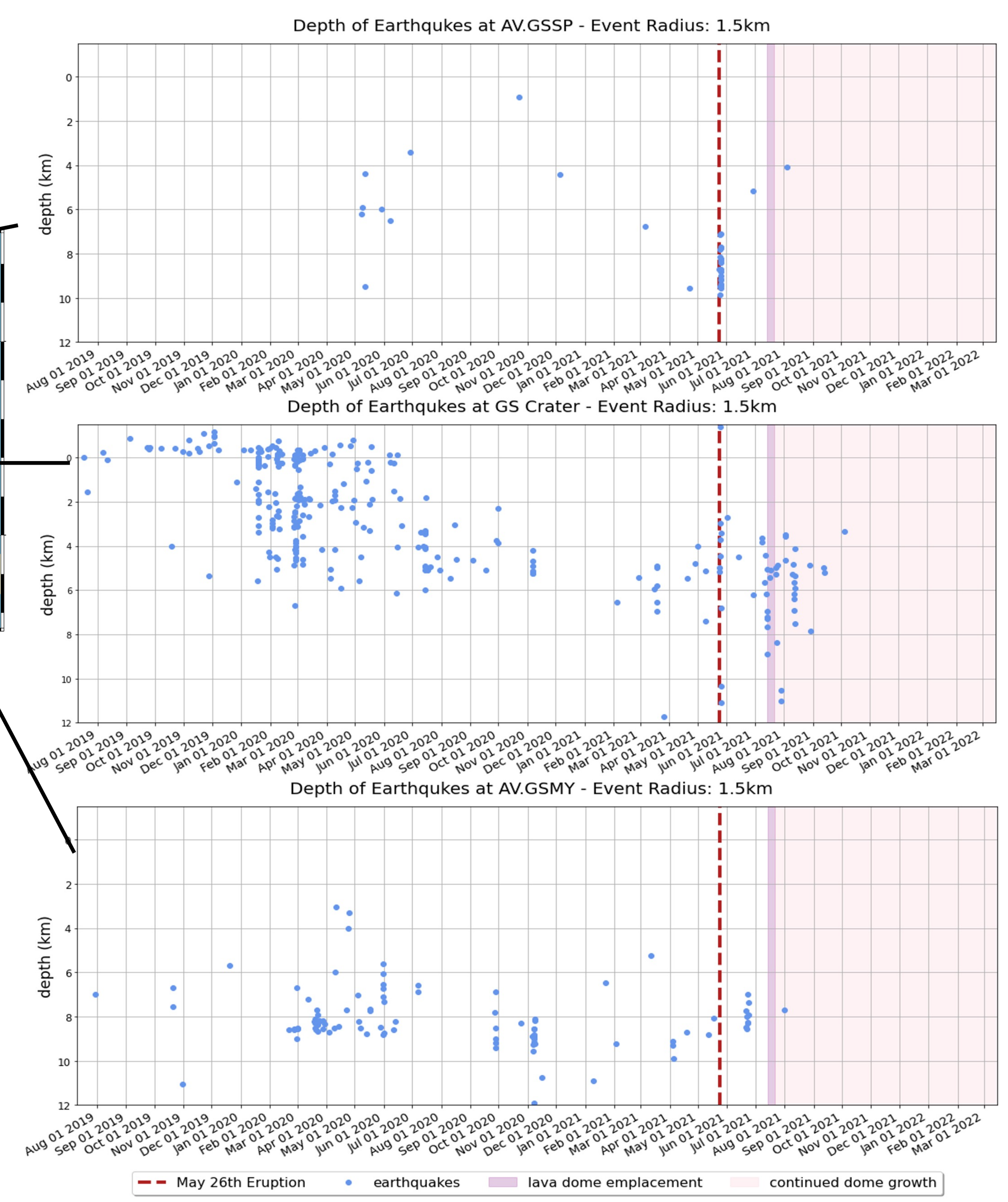
4. Seismicity

GS Volcano was seismically active in early 2020 with no eruption activity. An earthquake swarm occurred on the day of the eruption.



Key Observations:

- ***Earthquakes are primarily oriented in a NW-SE direction.***
- ***Earthquake swarm of May 26th, 2021, is located primarily NW of the crater.***

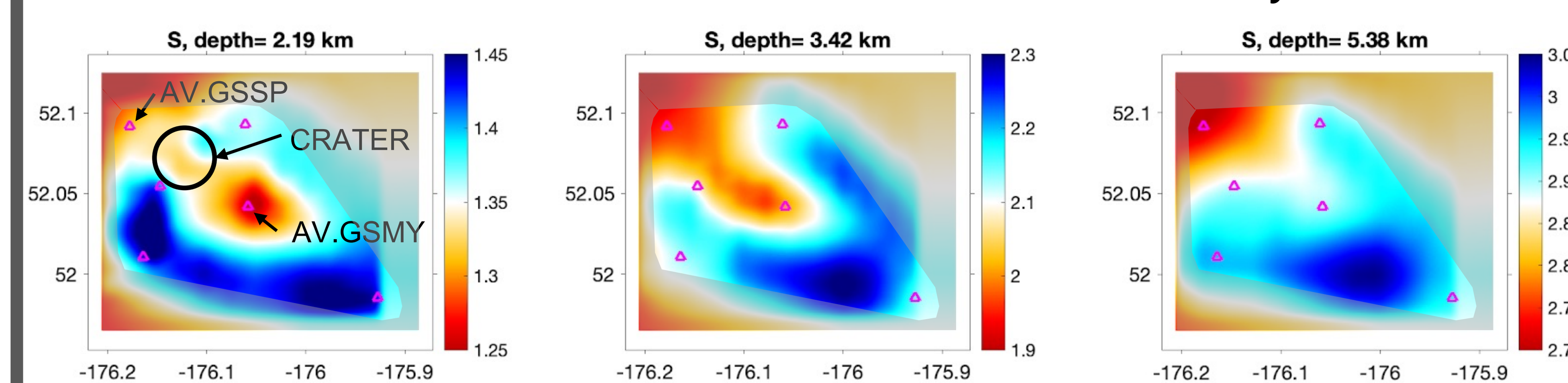


5. Upper crustal shear wave velocity model from full-wave ambient noise tomography

We extracted the empirical Green's functions from the vertical component of 5 stations from July 2019 to July 2020, with a sampling rate of 20 Hz. We conducted the full-wave ambient noise tomography with 8 overlapping frequency bands ranging from 0.3 Hz to 1 Hz. The results shown here are after 4 iterations.

Key Observations:

- ***A low-velocity zone is observed between 2-5km in a NW-SE direction — This is consistent with the seismicity observations.***



6. Conclusion

- The combined observations of the seismicity, the velocity model, and the change of seismic velocity for the cross-component at AV.GSSP suggest that the magma chamber for the Great Sitkin Volcano is below the NW of the island. The long-term decrease in dv/v is likely indicative of magma recharge.
- The local nature of the long-term decrease seen at AV.GSSP may suggest that the magma recharge does not affect the change in velocity across the whole region. As such, the stark drop in dv/v in August 2021 for the single-component results is unlikely magma related.
- The observed differences between single and cross–component results may suggest that the two methods are sensitive to different subsurface properties such as pressure and material changes, respectively