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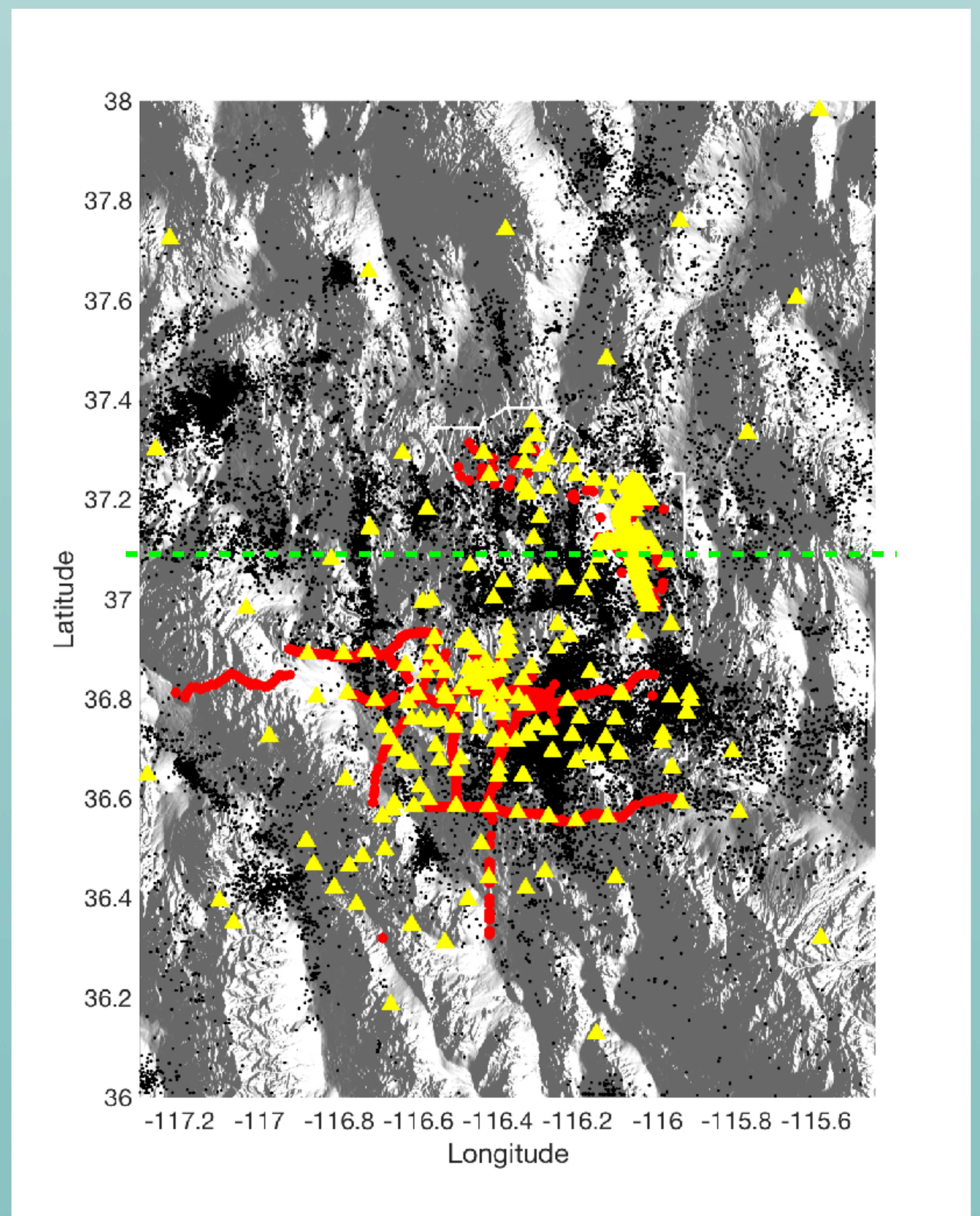
Regional 3-D Geophysical Characterization of the Nevada National Security Site

Leiph Preston (lpresto@sandia.gov), Christian Poppeliers, and David Schodt
Geophysics Department, Sandia National Laboratories, Albuquerque, NM

Sandia National Laboratories

Abstract

One of the goals of the Source Physics Experiments (SPE) is to gain a better understanding of the generation and evolution of seismic wave types over a range of propagation distances. A fundamental first step in this is to synthesize seismic waves, which requires accurate 3-D earth structural models. We have developed a 3-D local-to-regional scale seismic velocity model of the Nevada National Security Site using a joint inversion of body wave travel times, gravity measurements, and surface wave dispersion curves. The body wave data set includes absolute and differential P- and S-wave travel times from local earthquakes recorded on the University of Nevada Reno (UNR) southern Nevada network as well as active sources, including those from SPE. This data set alone amounts to over a million absolute body wave picks and over 500,000 high-quality differential picks. To enhance near-surface velocity resolution we also augment this data set with local measurements of gravity and surface wave dispersion. We have recently improved the 3-D earth model in Yucca Flat by including new local active source data, providing better coverage near the SPE sites. We used a weighted, linearized, iterative inversion scheme to combine these disparate data types in order to solve for the optimal 3-D P- and S-wave velocity model and hypocentral locations given observed data subject to model smoothness constraints. We discuss the effect of adding these new data on the earth model.

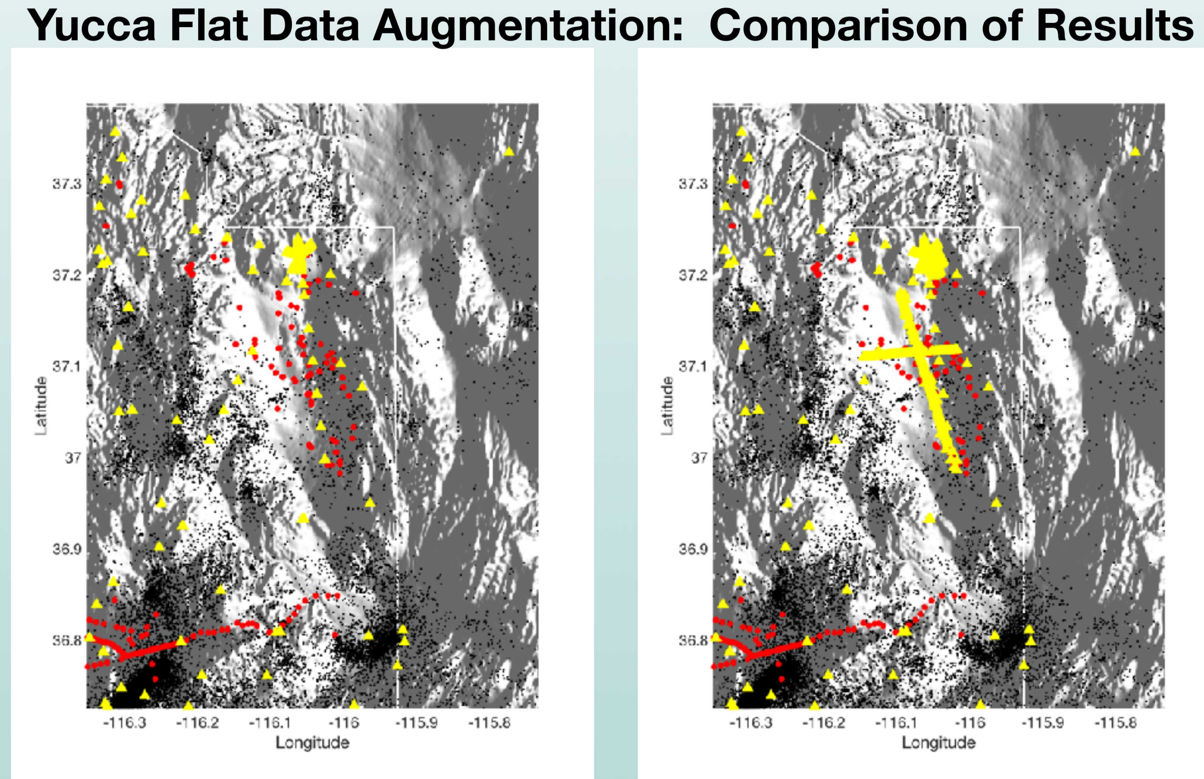


Overview map showing summary of seismic data used in the inversion: 535 stations (yellow triangles), 9084 active source events (red circles), 66815 earthquakes (black dots)

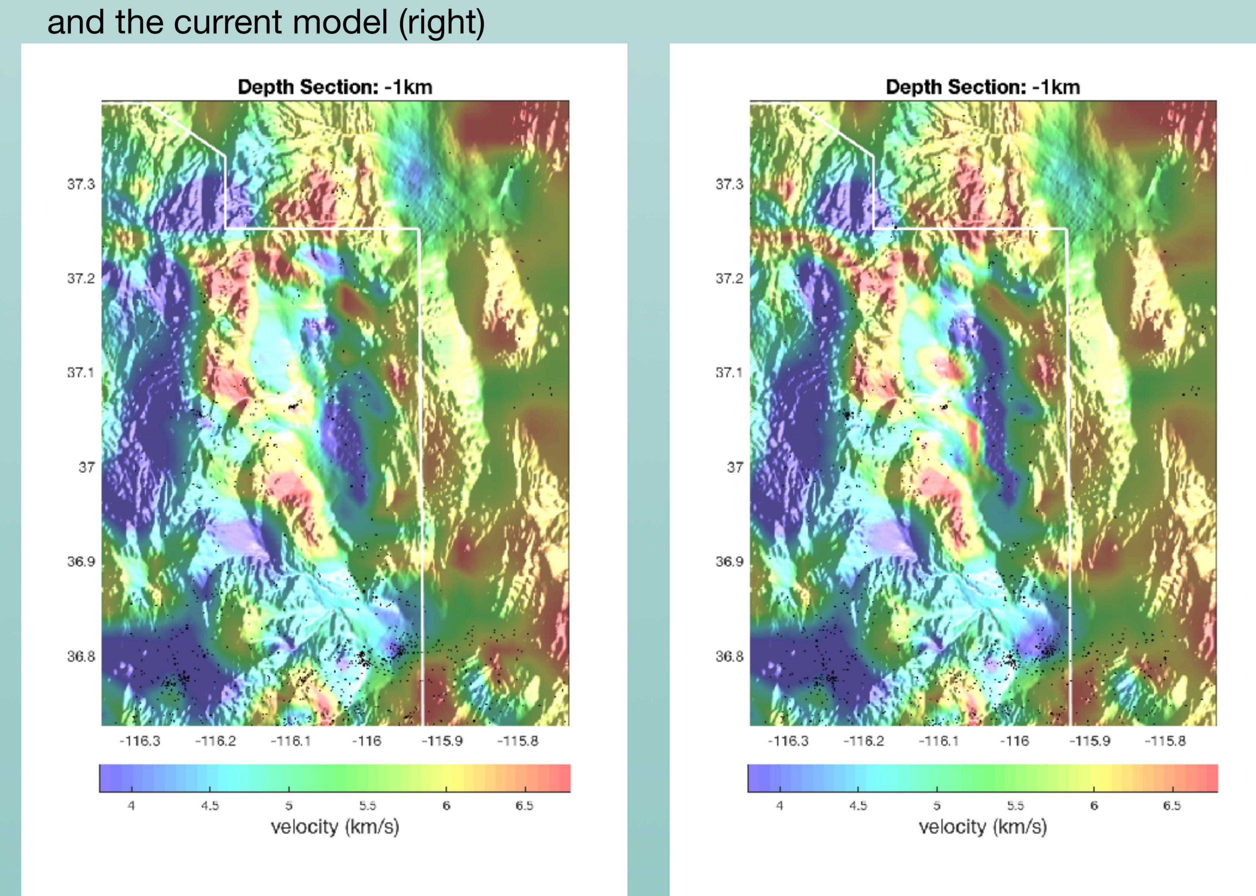
Data Sources

- P- and S-wave absolute and differential travel times for earthquakes from 2000-2014 are derived from University of Nevada Reno southern Nevada network. Differential picks are courtesy of David von Seggern at UNR
- P travel times from the SPE Large-N array from Ting Chen of Los Alamos National Laboratory
- P travel times and surface wave dispersion from the THOR1 and THOR2 experiments from Rob Abbott of Sandia National Laboratories
- Gravity data from the University of Texas El Paso's (UTEP) gravity and magnetic national data repository (http://research.utep.edu/Default.aspx?tabid=37229)
- P travel times from active source experiments derived from the USGS and other local networks, courtesy of Tom Brocher of the USGS.
- Dispersion curves from ambient noise of UNR stations and source interferometry from the SPE and large-N arrays picked by our team

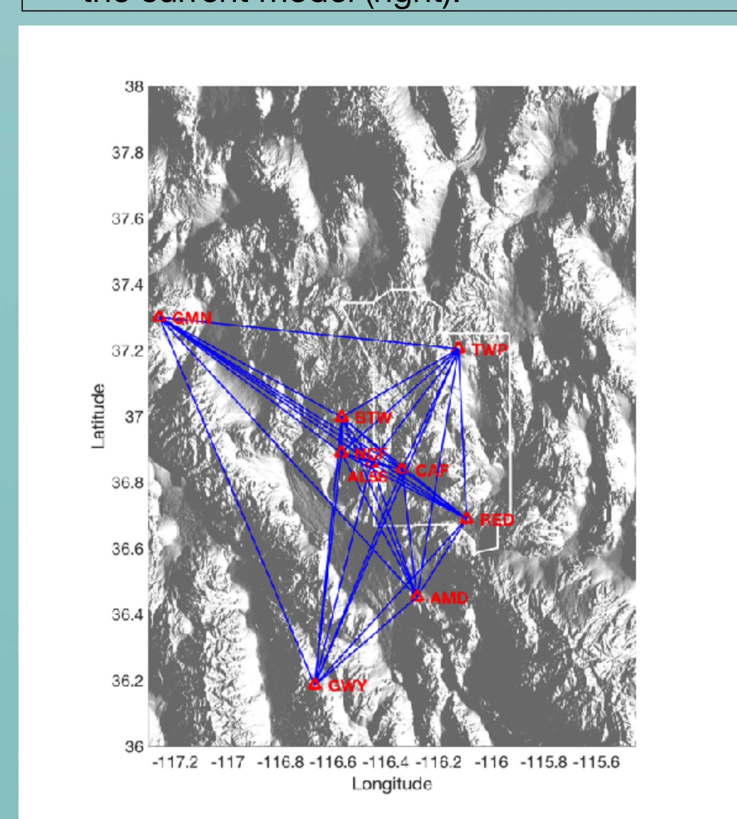
Yucca Flat Data Augmentation: Comparison of Results



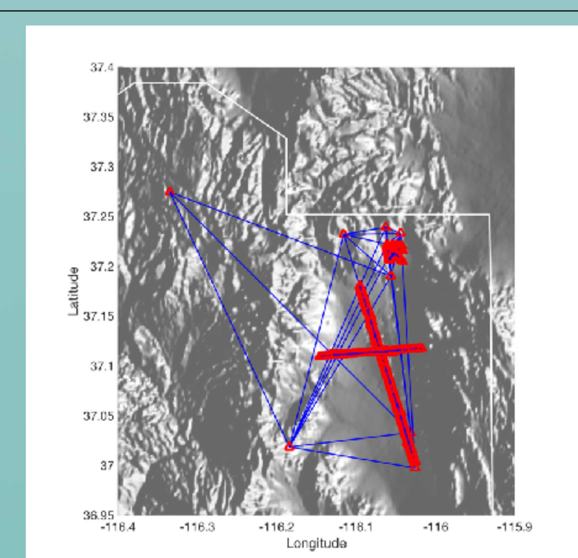
Comparison of data coverage in Yucca Flat between the original dataset (left) and the current model (right)



Vp at 1 km above sea level: Comparison between the original dataset (left) and the current model (right).



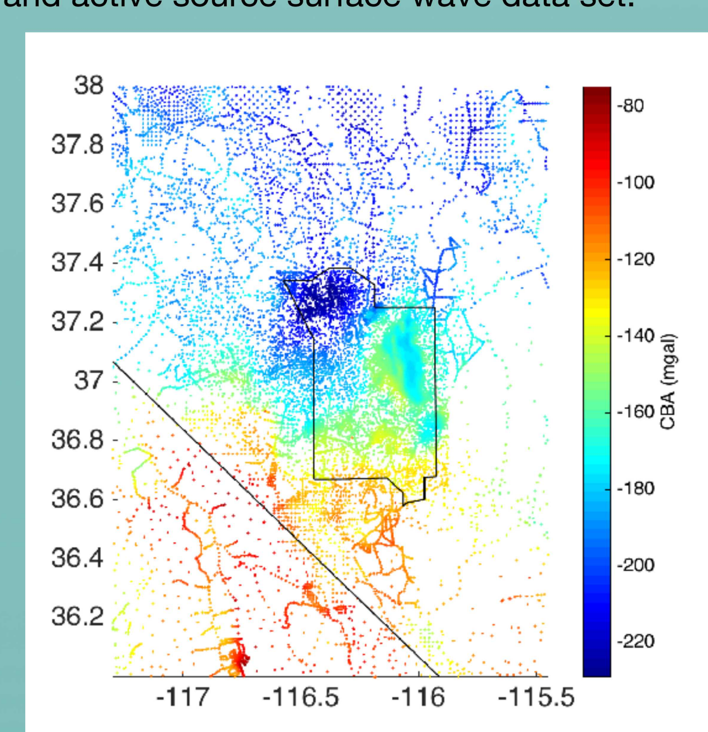
UNR stations ambient noise surface wave data set.



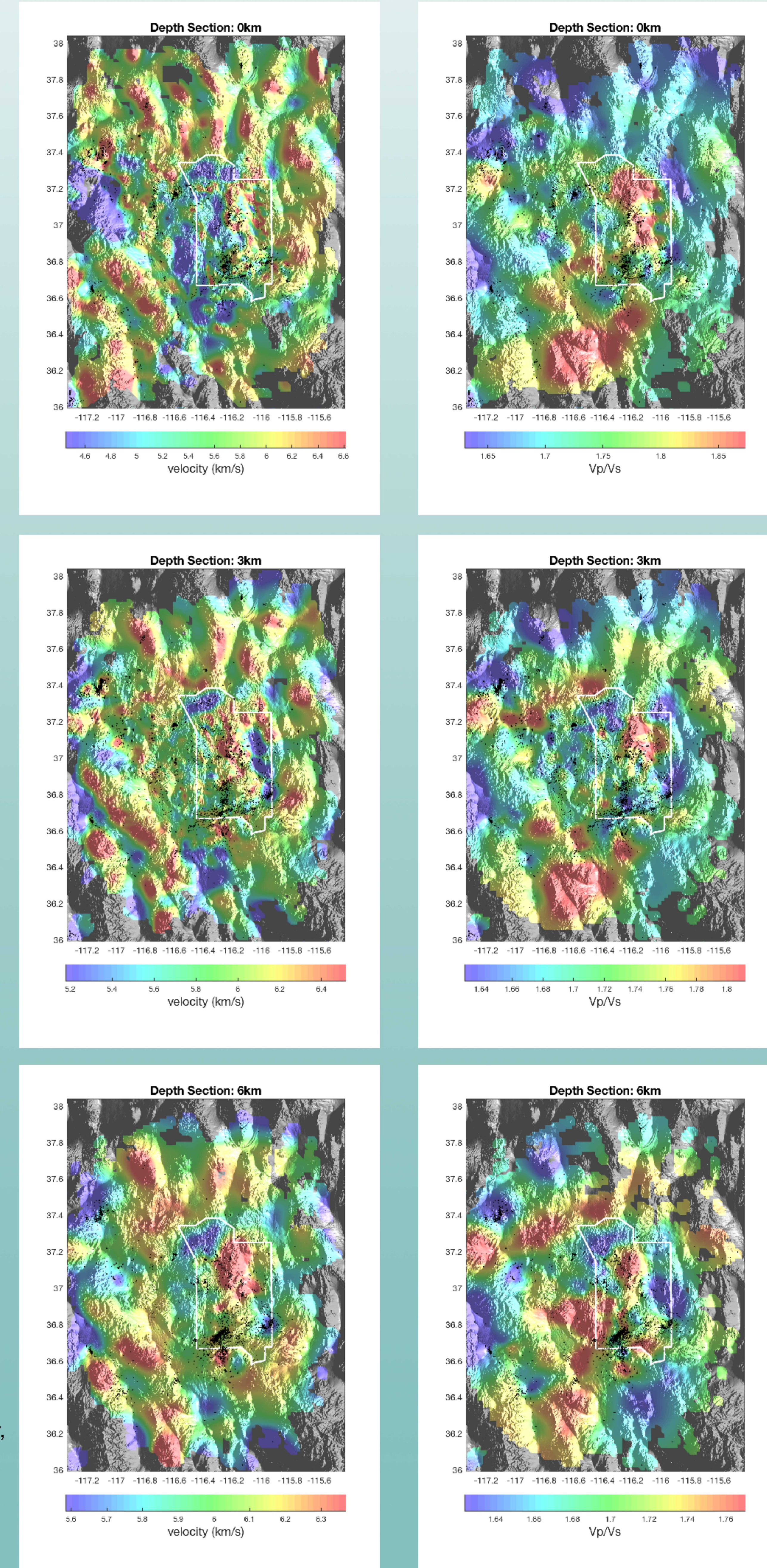
NE NNSS ambient noise, source interferometry, and active source surface wave data set.

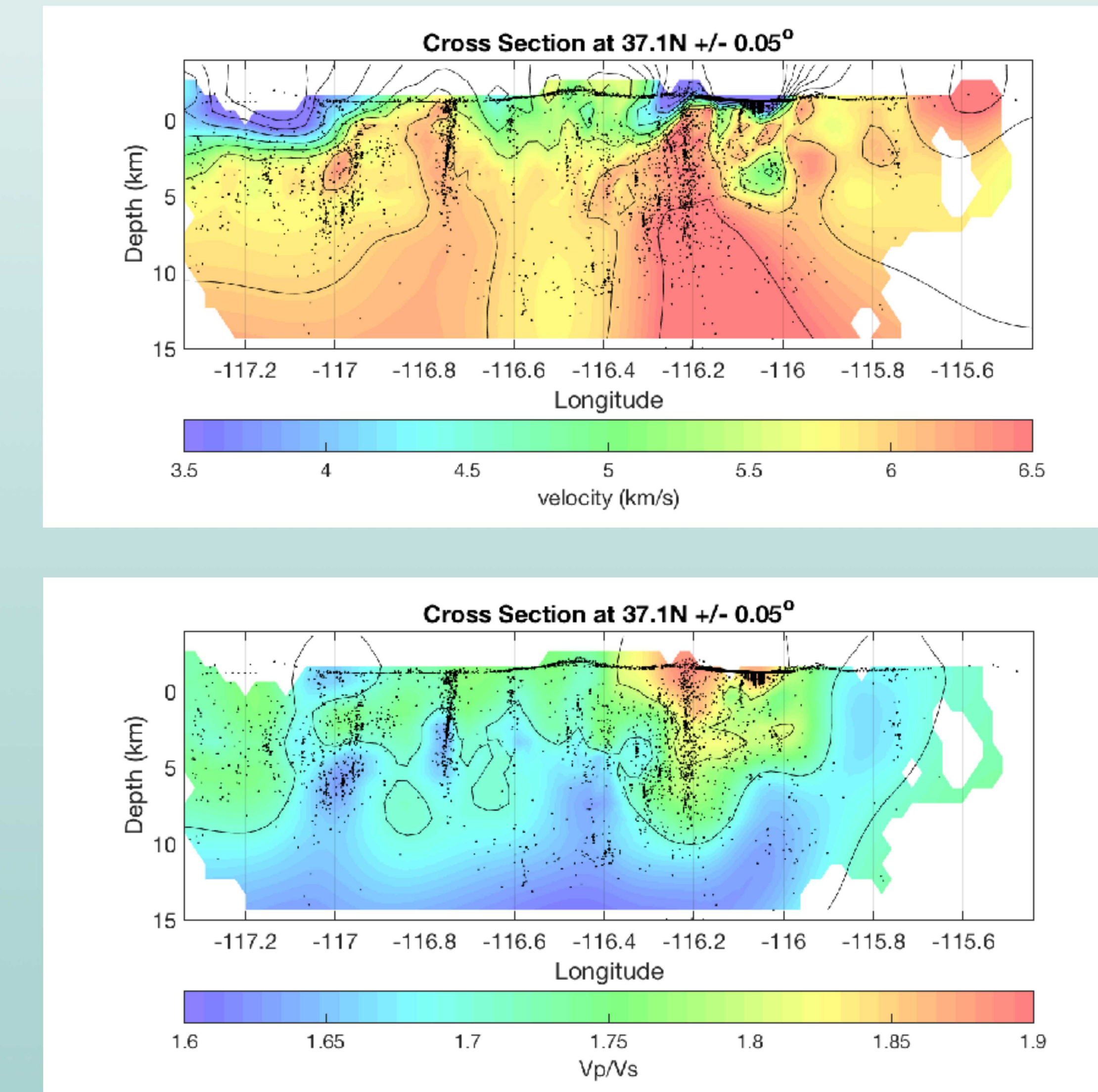
Data Type	Number	wRMS
Abs P	738,833	0.06 s
Abs S	344,789	0.09 s
Diff P	297,254	7 ms
Diff S	197,034	7 ms
Gravity	24,723	5 mgal
Group	92,105	0.23 km/s
Phase	347	0.08 km/s

Final weighted RMS (wRMS) for each of the data types



Gravity measurement points (complete Bouguer Anomalies (CBA))





Depth sections for Vp and Vp/Vs at 0, 3, and 6 km depth relative to sea level (left). Cross-sections (above) of Vp and Vp/Vs through the middle of Yucca Flat (green dashed line in Overview map).

Method

- Body wave travel times and sensitivities were computed using 3-D ray tracing via the Vidale-Hole eikonal solver (Vidale, 1988; Hole, 1992)
- Surface wave dispersion curves were calculated using a finite-element solver (Haney and Tsai, 2017). Sensitivities were derived from finite-frequency kernels (Lin and Ritzwoller, 2010) to approximate the 3-D volume sampled by the Rayleigh waves.
- Gravity inversions use a weighted combination of Gardner's rule and Brocher (2005) to find a Vp-density relationship
- Absolute and differential P- and S-body waves, surface wave dispersion, and gravity data were combined into a joint iterative inversion procedure to solve for 3-D P- and S-wave structural images
- P- and S-wave models are constrained to be smooth and lie between upper and lower velocity limits as a function of depth. Vp/Vs is also bounded.

Discussion

- Additional data in Yucca Flat allows clear distinction between the east and west sides of the basin, especially in the north. Differences persist down to ~6 km depth, but with lesser differences in deeper portions.
- Shallow depth sections show clear basin and range structure: high velocity ranges and low velocity basins in Vp. This is primarily controlled by gravity data.
- Vp clearly has higher resolution in the shallow portions compared to Vs due to much greater coverage of active source data. Much shallow Vs structure is due to surface wave dataset, which has lower resolution.
- Combining disparate data types formed a more robust image of the 3-D structure of the region. The strengths of each data type mitigate against weaknesses and non-uniqueness in the other data types. This allows greater resolution than would be possible when using one data type alone.
- Next step: Error and resolution analysis

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