Offshore Pacific-North America lithospheric structure and Tohoku tsunami observations from a southern California ocean bottom seismometer experiment

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Collaborators

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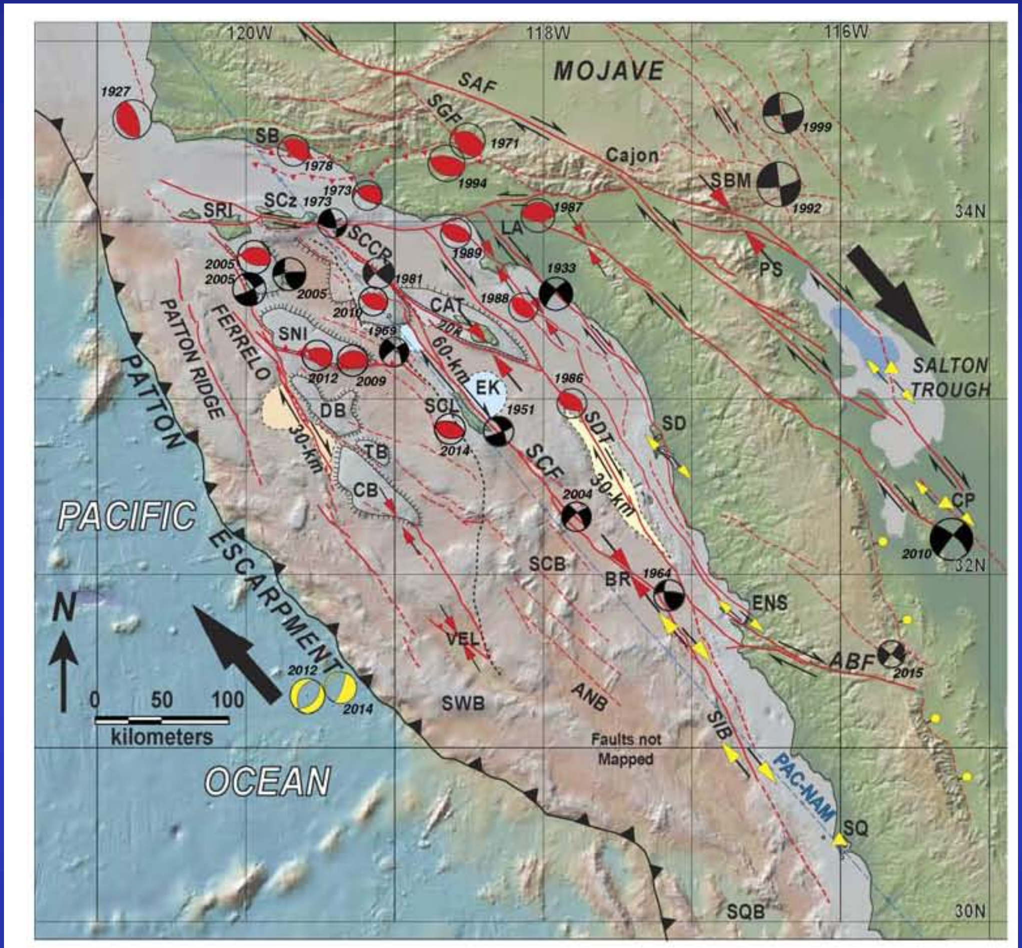
NSF

USGS science for a changing world

SCEC

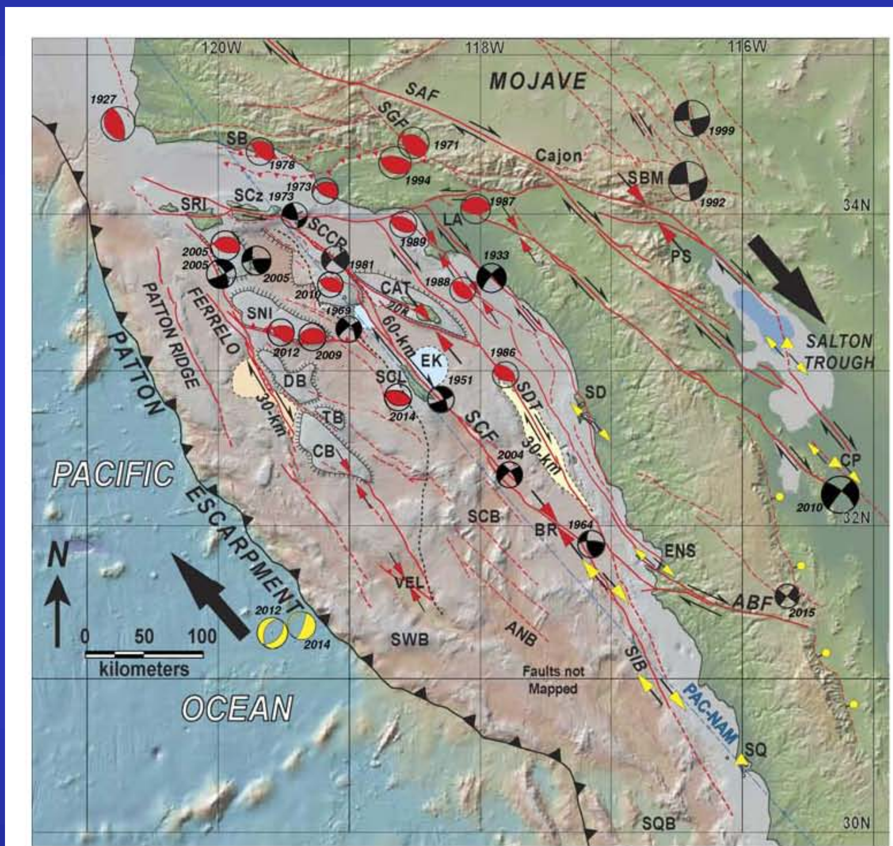


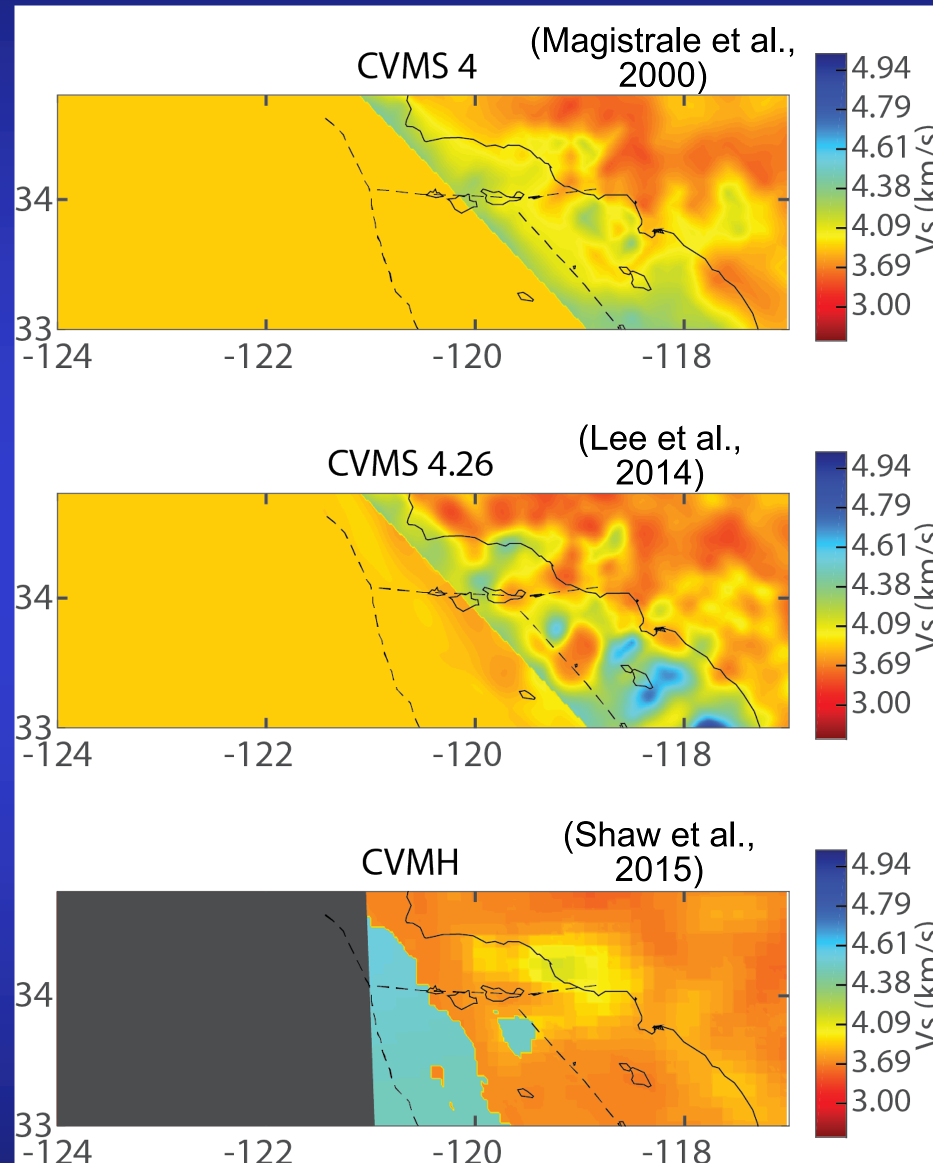
Legg et al., JGR, 2015

- Tectonic: Seismic velocity structure below and across plate boundary
  - Presence/absence of upper mantle high-velocity anomalies or remnant slabs.
  - Crustal and mantle lithospheric thickness variations.
  - Degree of coupling with underlying mantle flow.

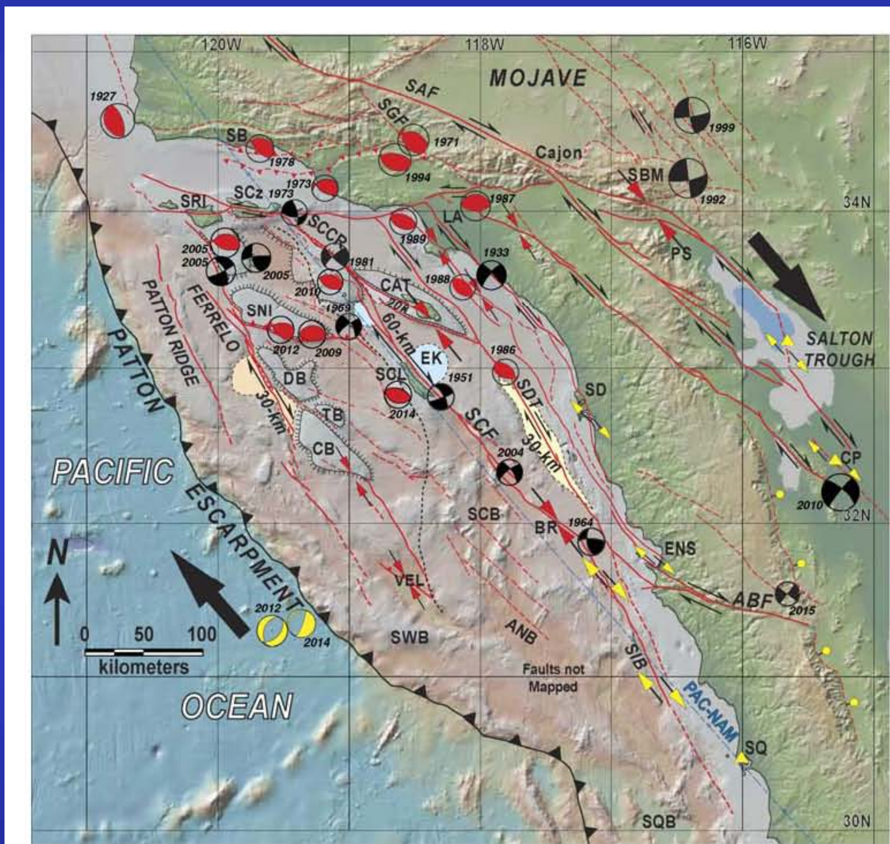
- Hazard and risk analysis:
  - Fault structures and seismic potential.
  - Wave propagation and ground motion predictions.

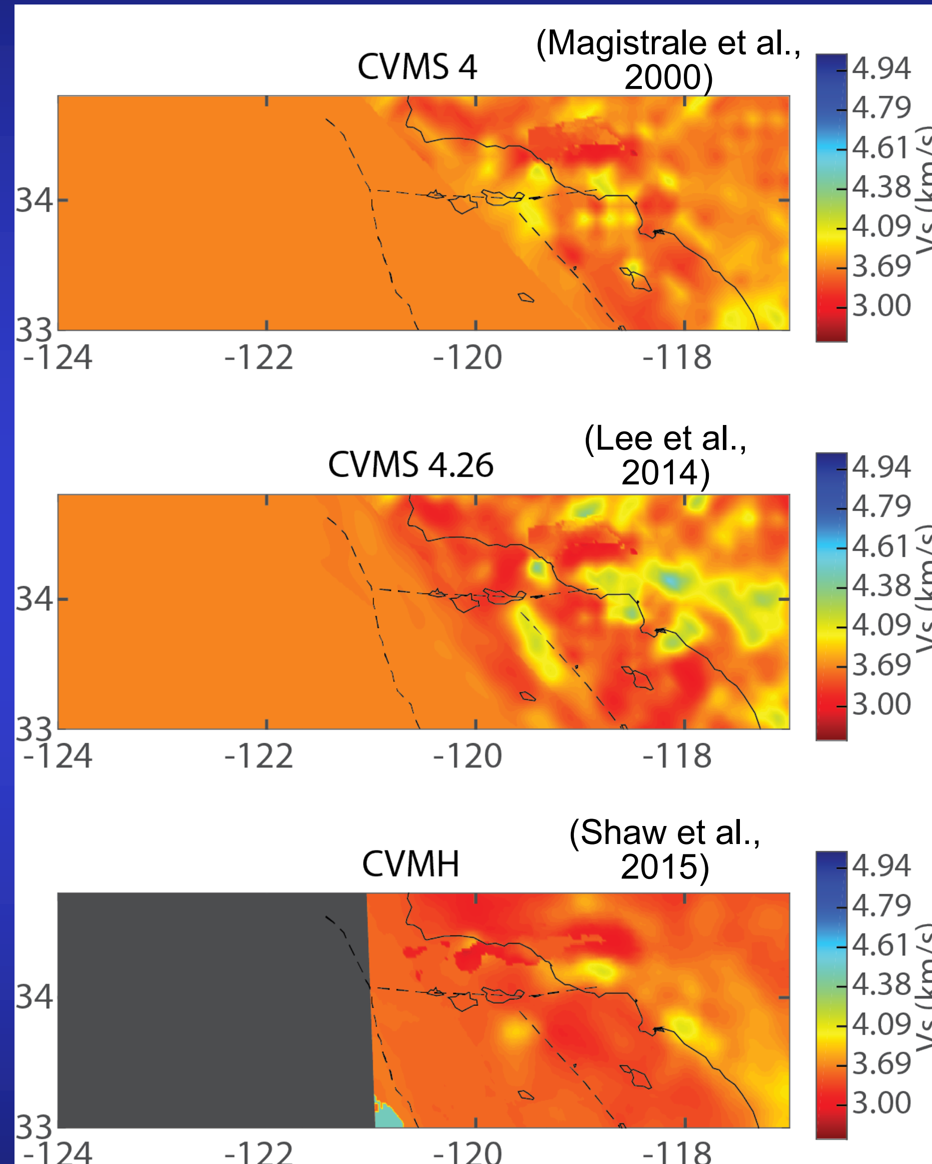
SCEC Community Seismic Velocity Model
20 km depth

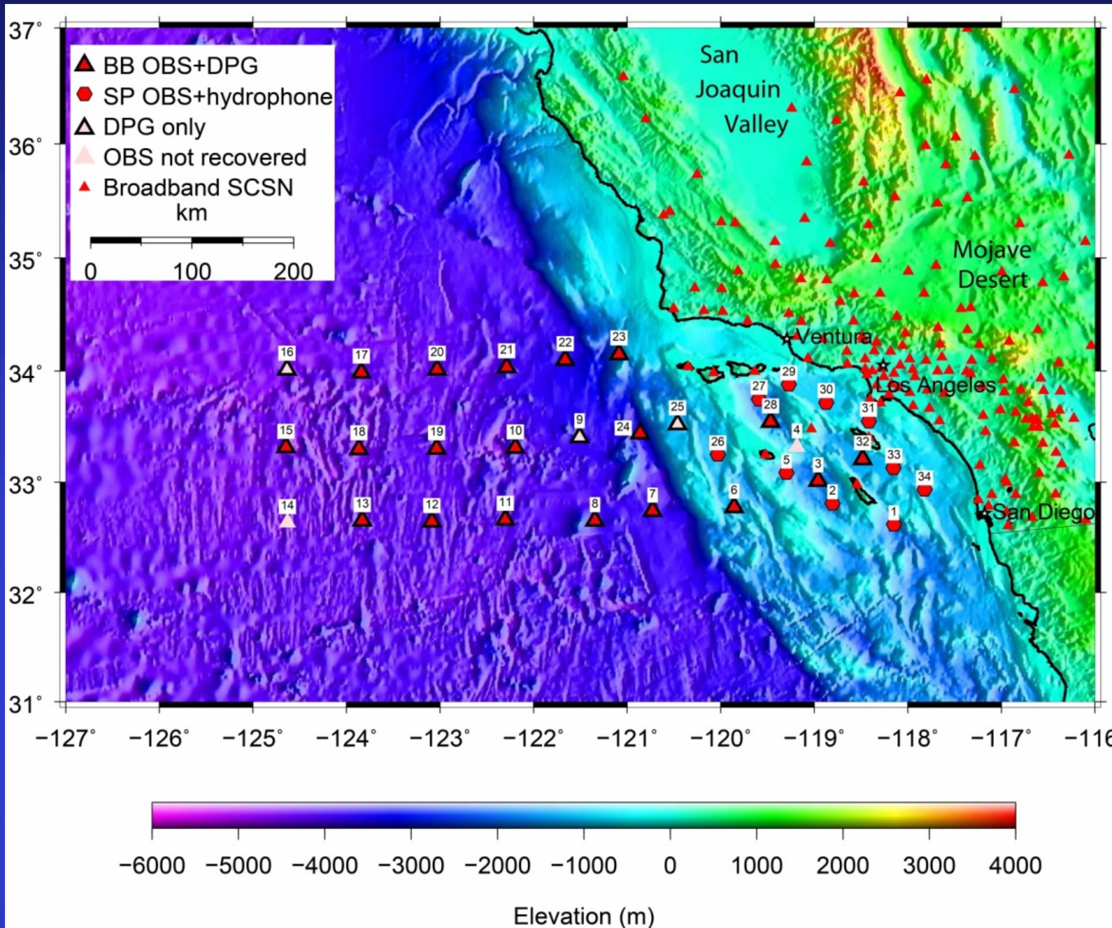




SCEC Community Seismic Velocity Model
10 km depth



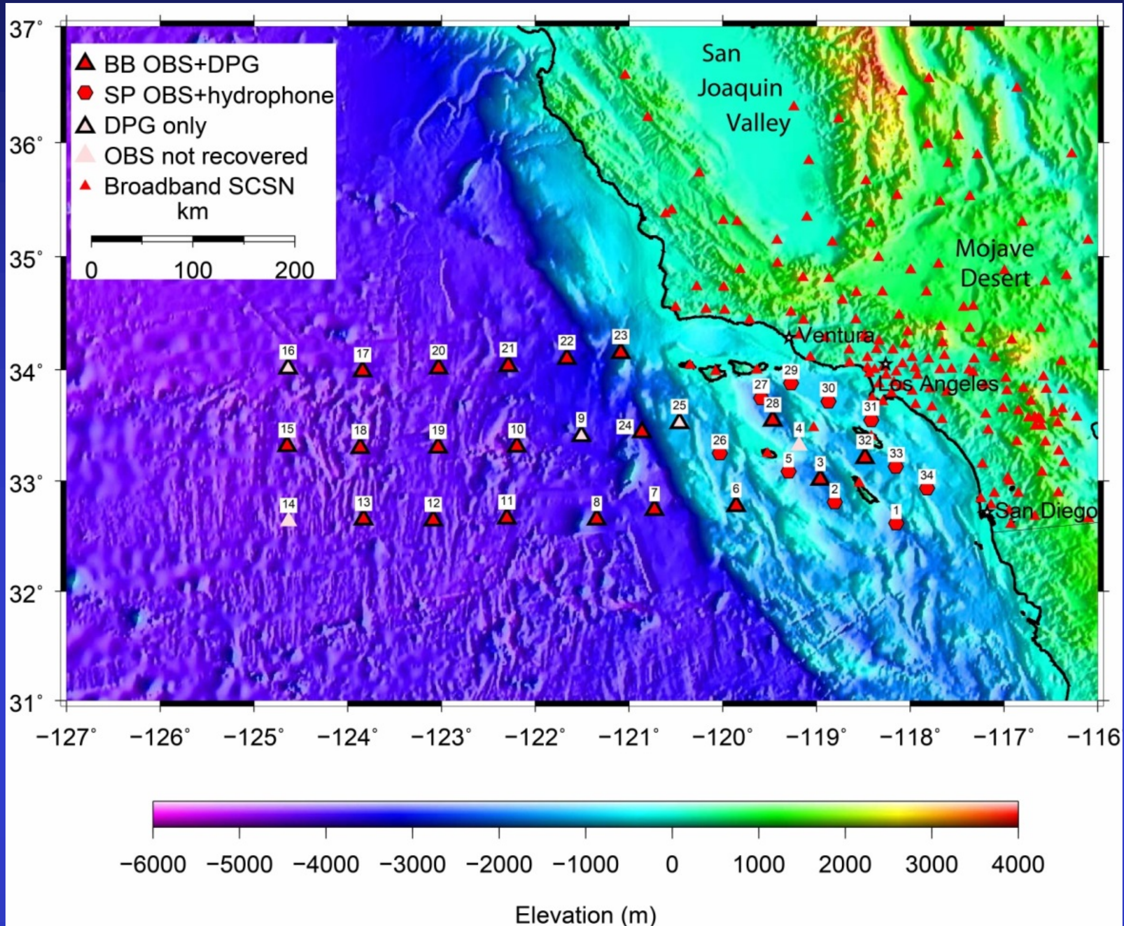




ALBACORE: Asthenospheric and Lithospheric Broadband Architecture from the California Offshore Region Experiment

Aug. 2010- Sept. 2011

- 24 broadband & 10 short-period OBSs.
- Collection of continuous, 50 sps, 3-component velocity and pressure waveforms.
- Teleseismic and local earthquakes, ambient vibrations, pressure waves.
- Concurrent collection of bathymetry, gravity, magnetic, near-surface sedimentation, temperature profiles.

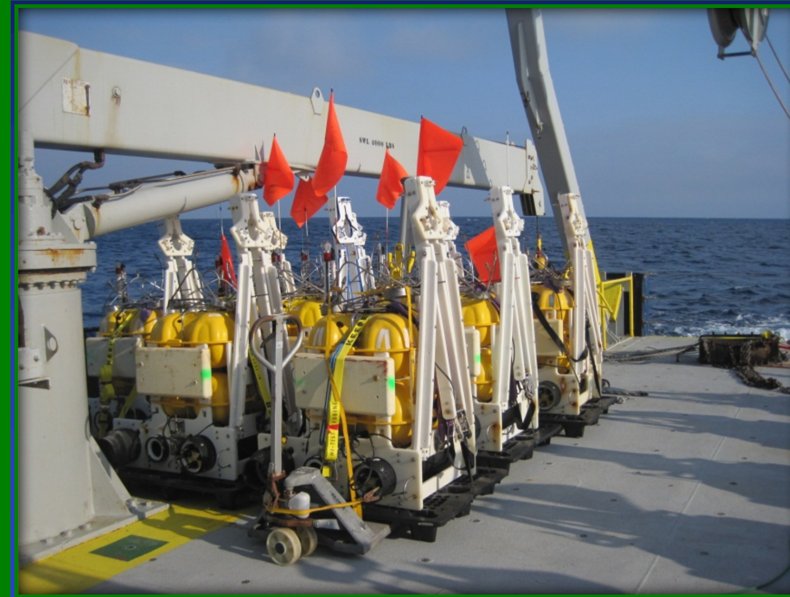


ALBACORE: Asthenospheric and Lithospheric Broadband Architecture from the California Offshore Region Experiment

Aug. 2010- Sept. 2011

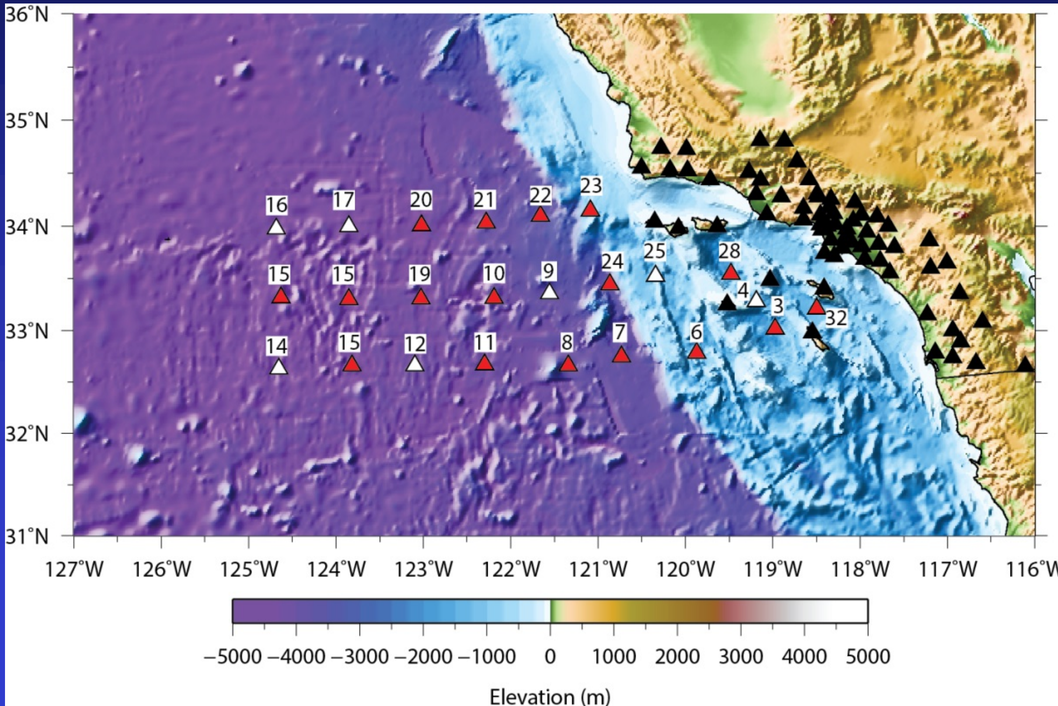
- **Crustal and mantle lithospheric seismic velocities and thicknesses across plate boundary from noise cross correlations.**
- Anisotropy from SKS splitting and surface waves.
- Seismic velocities from surface waves.
- Moho and lithosphere-asthensphere interface geometry from receiver functions.
- Offshore hypocenters, seismicity patterns, fault geometries.

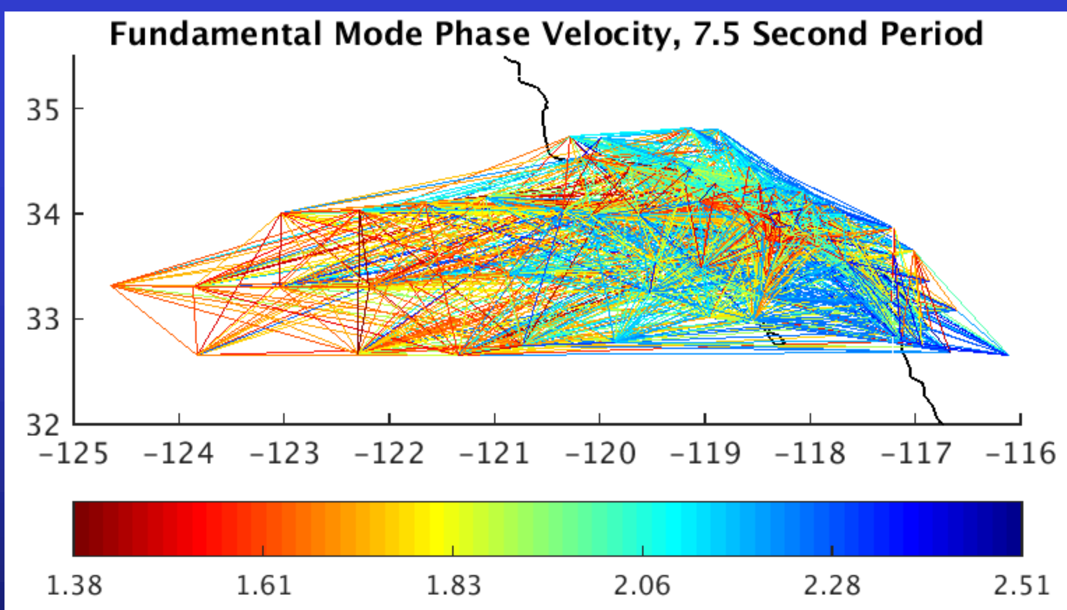

MELVILLE
SAN DIEGO
NO
PARKING



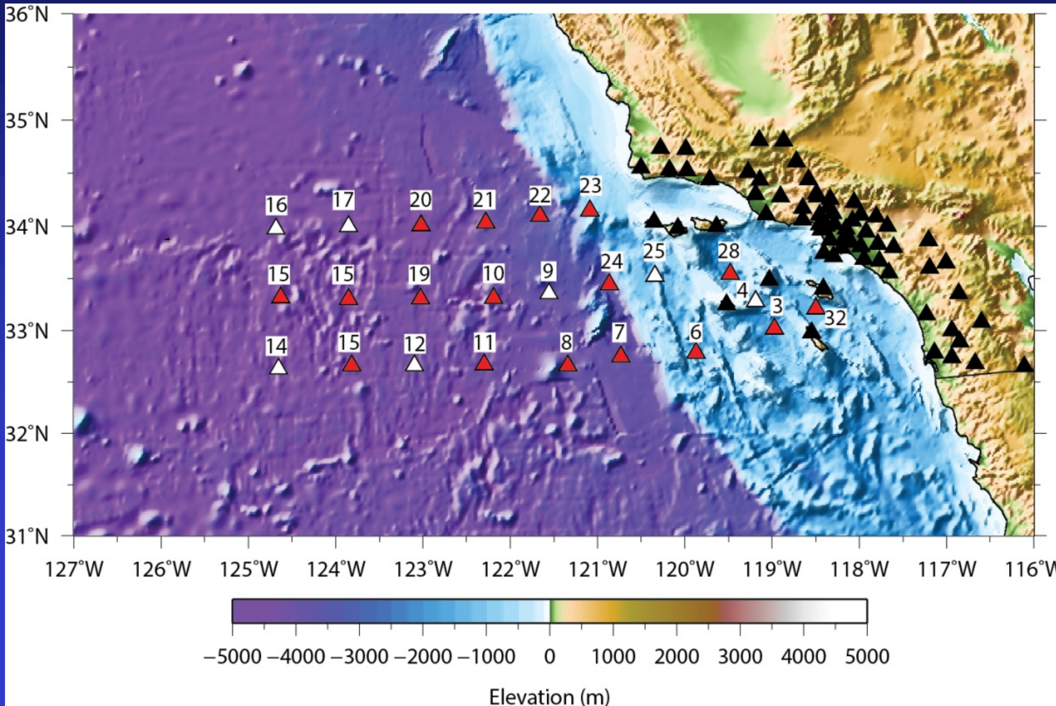

MELVILLE

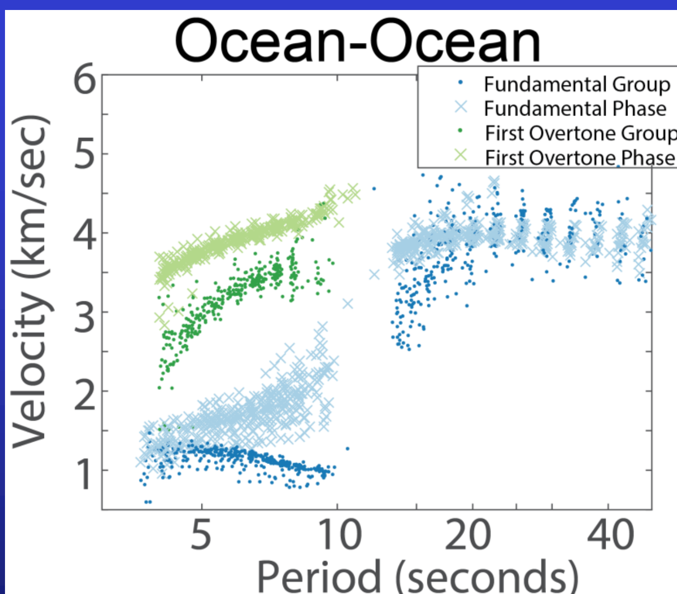
Seismic Shear-Wave Velocity from Ambient Noise Cross Correlation Functions

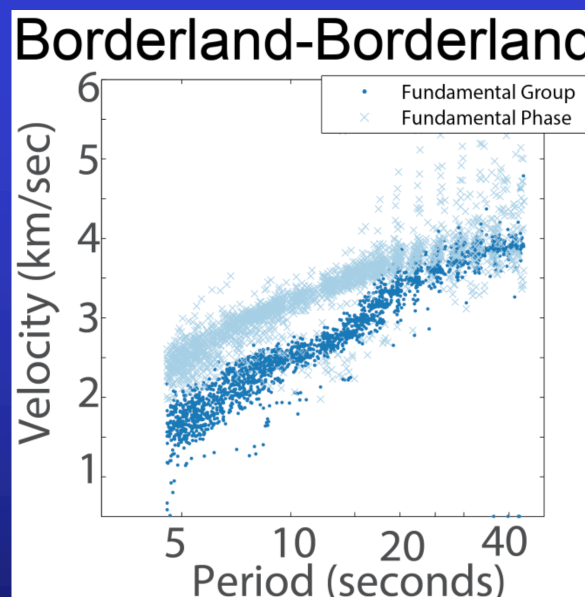


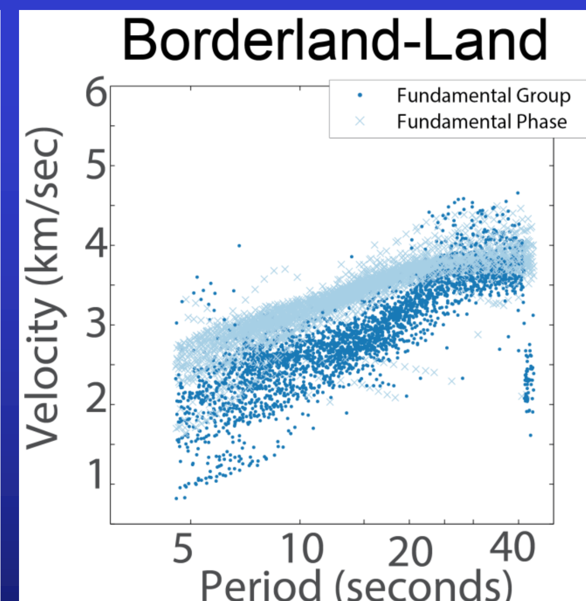


- 5-50 s, 0-100 km depth.
- Total 3321 station pairs.
  - Up to ~1400 rays for 6-40 s fundamental.
  - ~50 rays for 1st overtone in deep ocean 6-10 s.
- Shear-wave velocities from inversion of dispersion curves.
  - 2D grid of phase and group velocities at 20 periods.
  - 1D shear-wave velocities at each grid point from inversion of dispersion curves.
  - averaging 1D grid point velocities for 3D model.

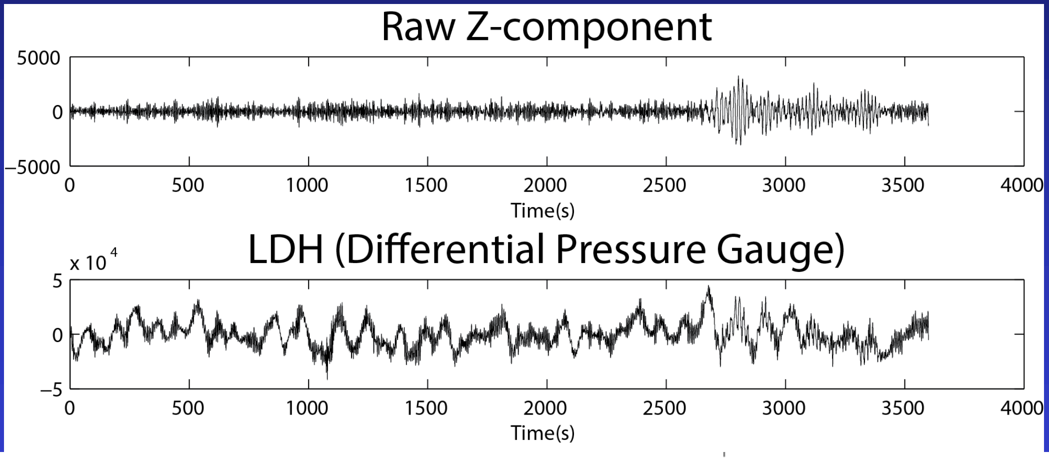

36°N
35°N
34°N
33°N
32°N
31°N
127°W 126°W 125°W 124°W 123°W 122°W 121°W 120°W 119°W 118°W 117°W 116°W
−5000 −4000 −3000 −2000 −1000 0 1000 2000 3000 4000 5000
Elevation (m)

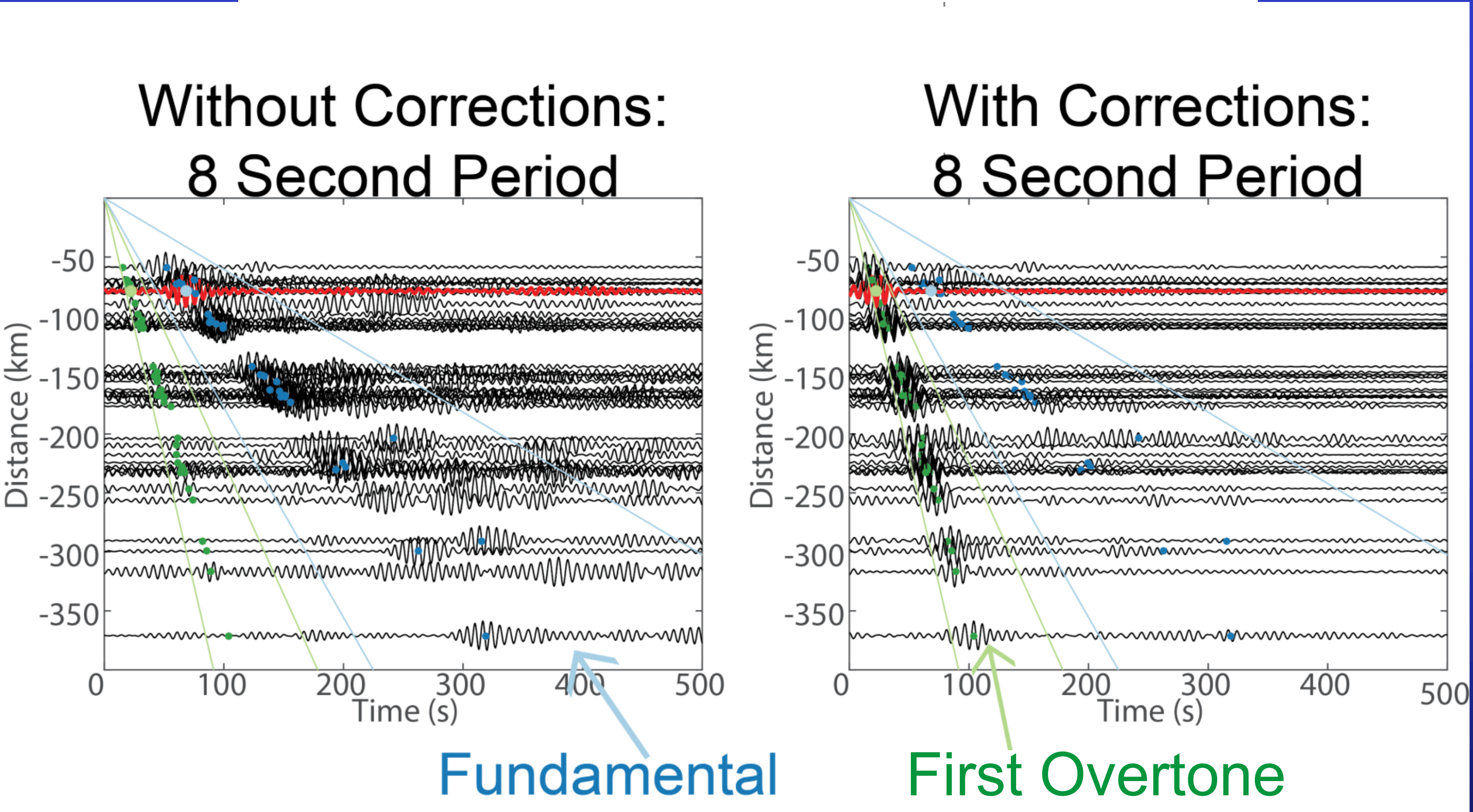

Ocean-Ocean
Fundamental Group
Fundamental Phase
First Overtone Group
First Overtone Phase
Velocity (km/sec)
Period (seconds)


Borderland-Borderland
Fundamental Group
Fundamental Phase
Velocity (km/sec)
Period (seconds)

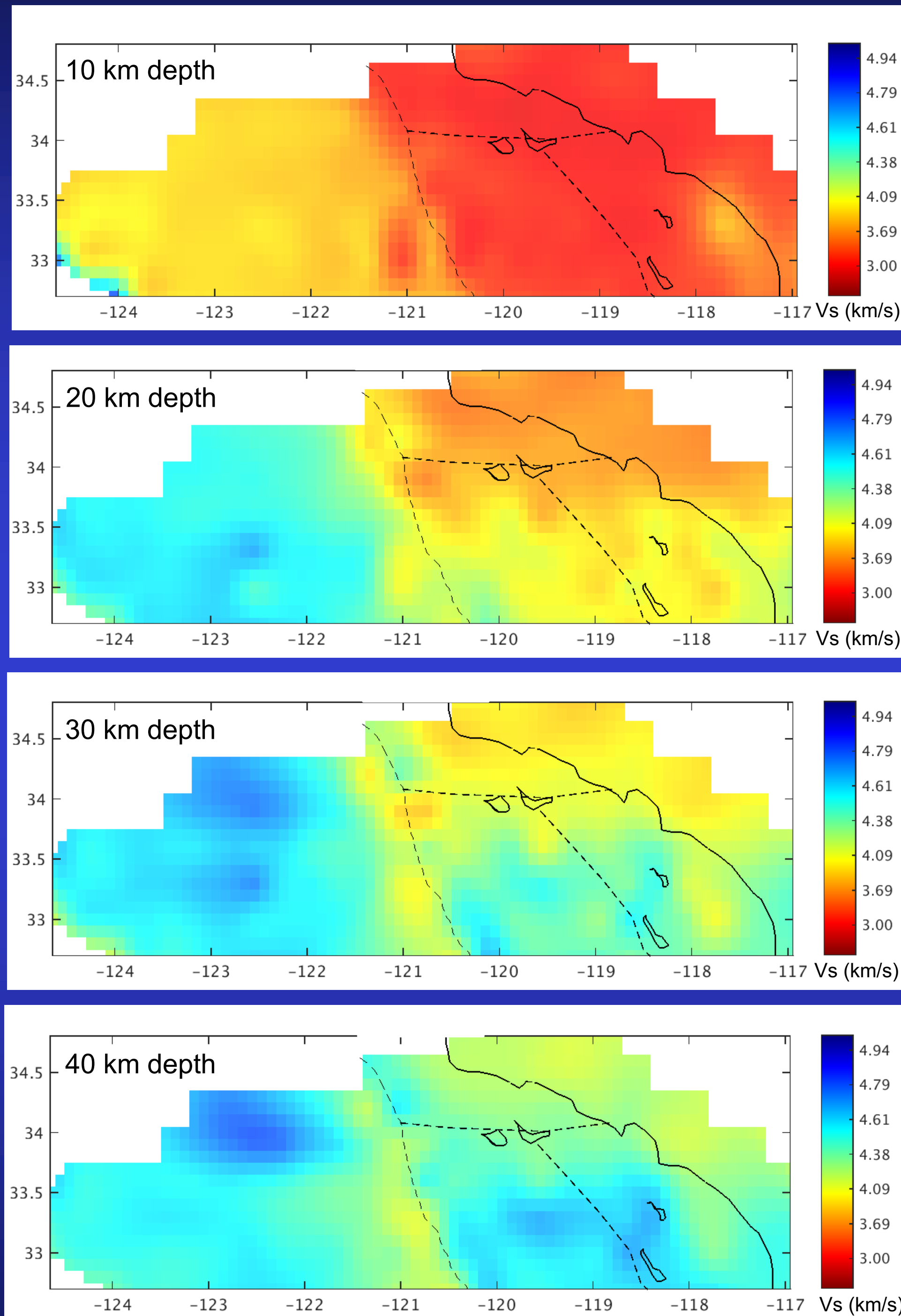

Borderland-Land
Fundamental Group
Fundamental Phase
Velocity (km/sec)
Period (seconds)

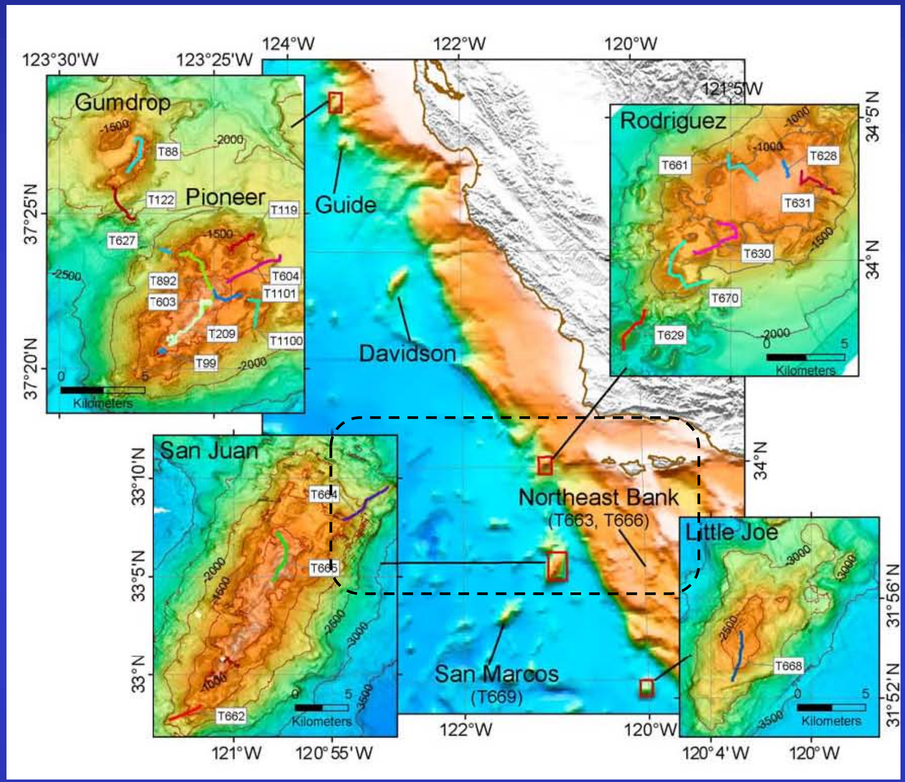
Wave loading correction using pressure gauge waveforms





Shear-wave velocities from inversion of NCF dispersion curves

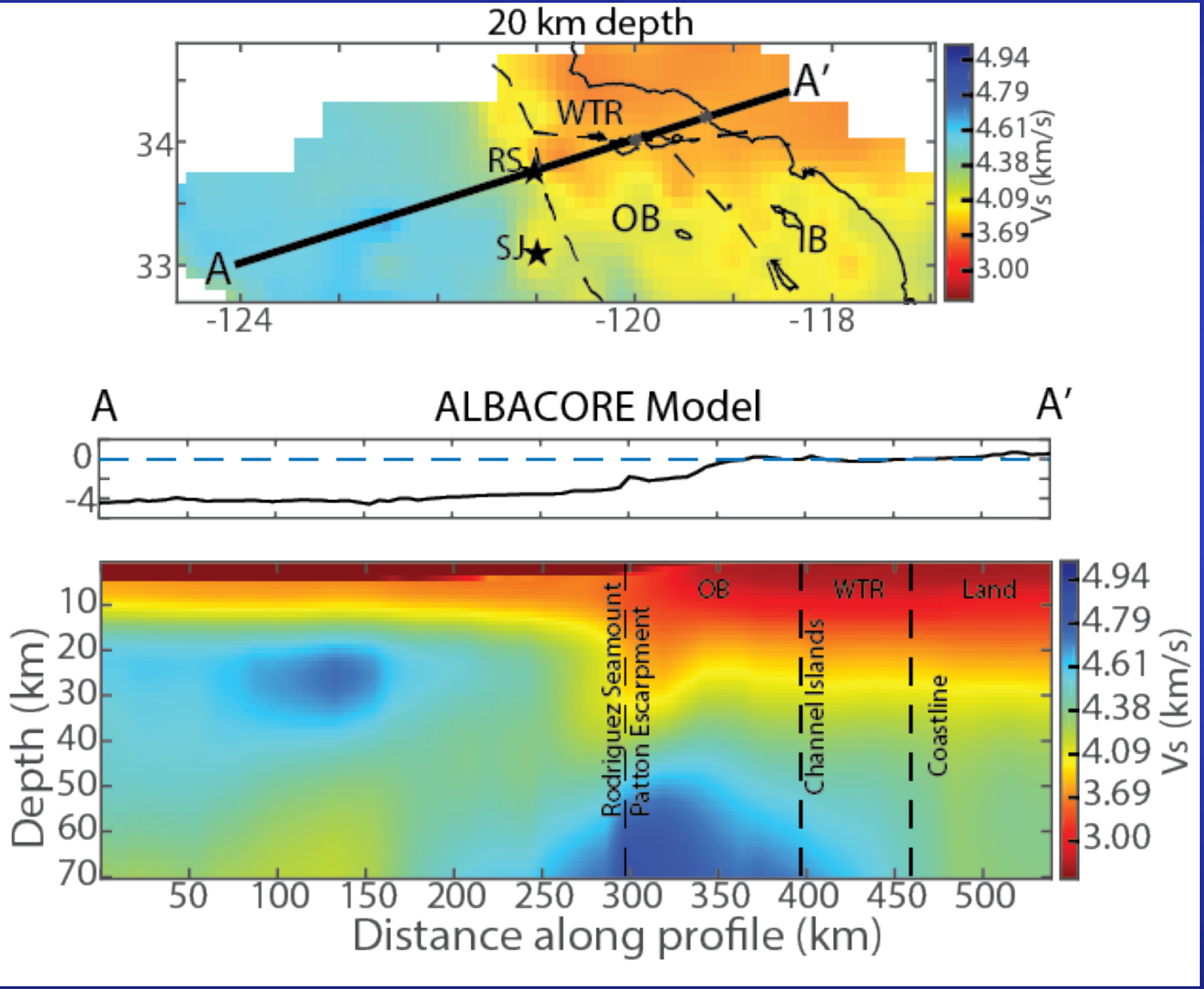




Davis et al., G-cubed, 2010

Bowden et al., JGR, 2016

Shear-wave velocity model: A-A′



WTR: Western Transverse Ranges

IB: Inner Borderland

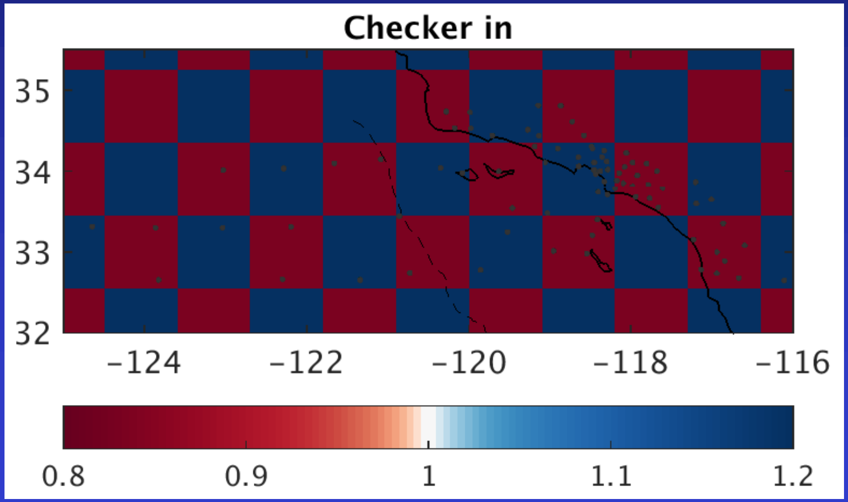
OB: Outer Borderland

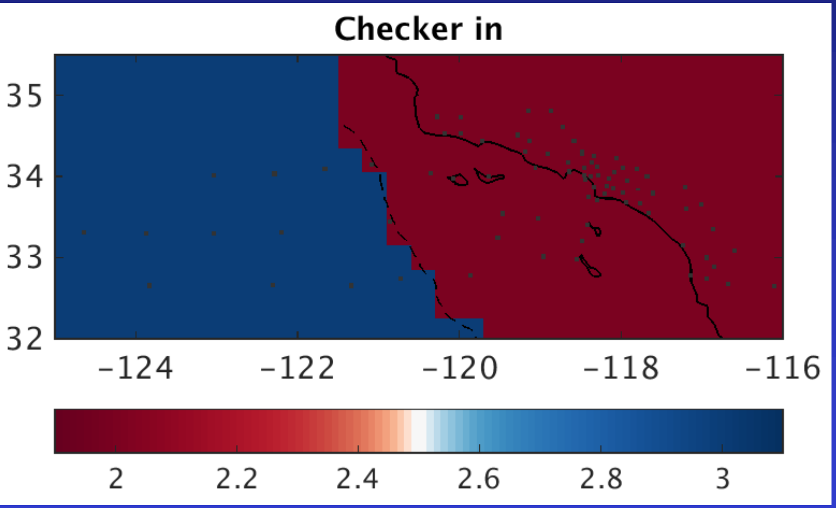
RS: Rodriguez Seamount

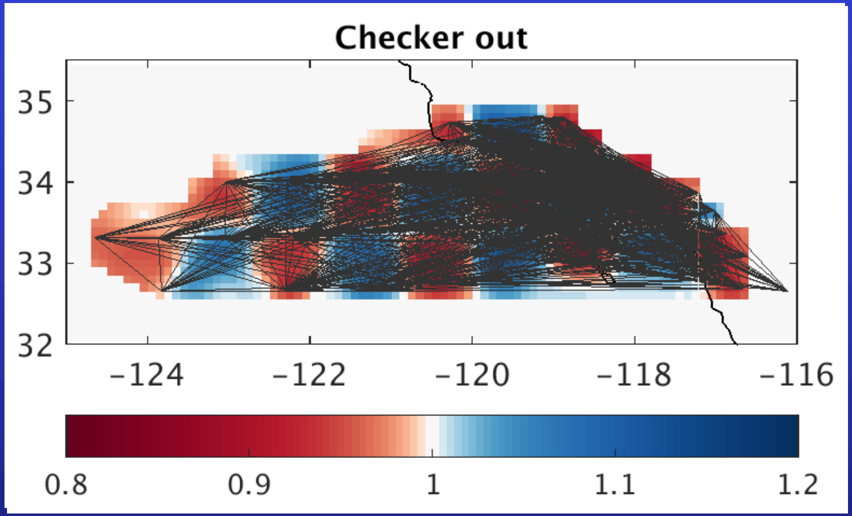
SJ: San Juan Seamount

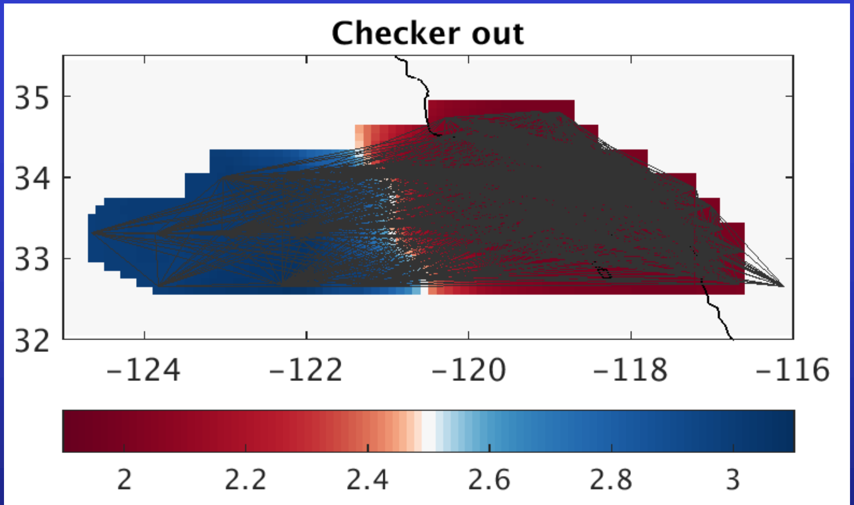
Bowden et al., JGR, 2016

Resolution Tests

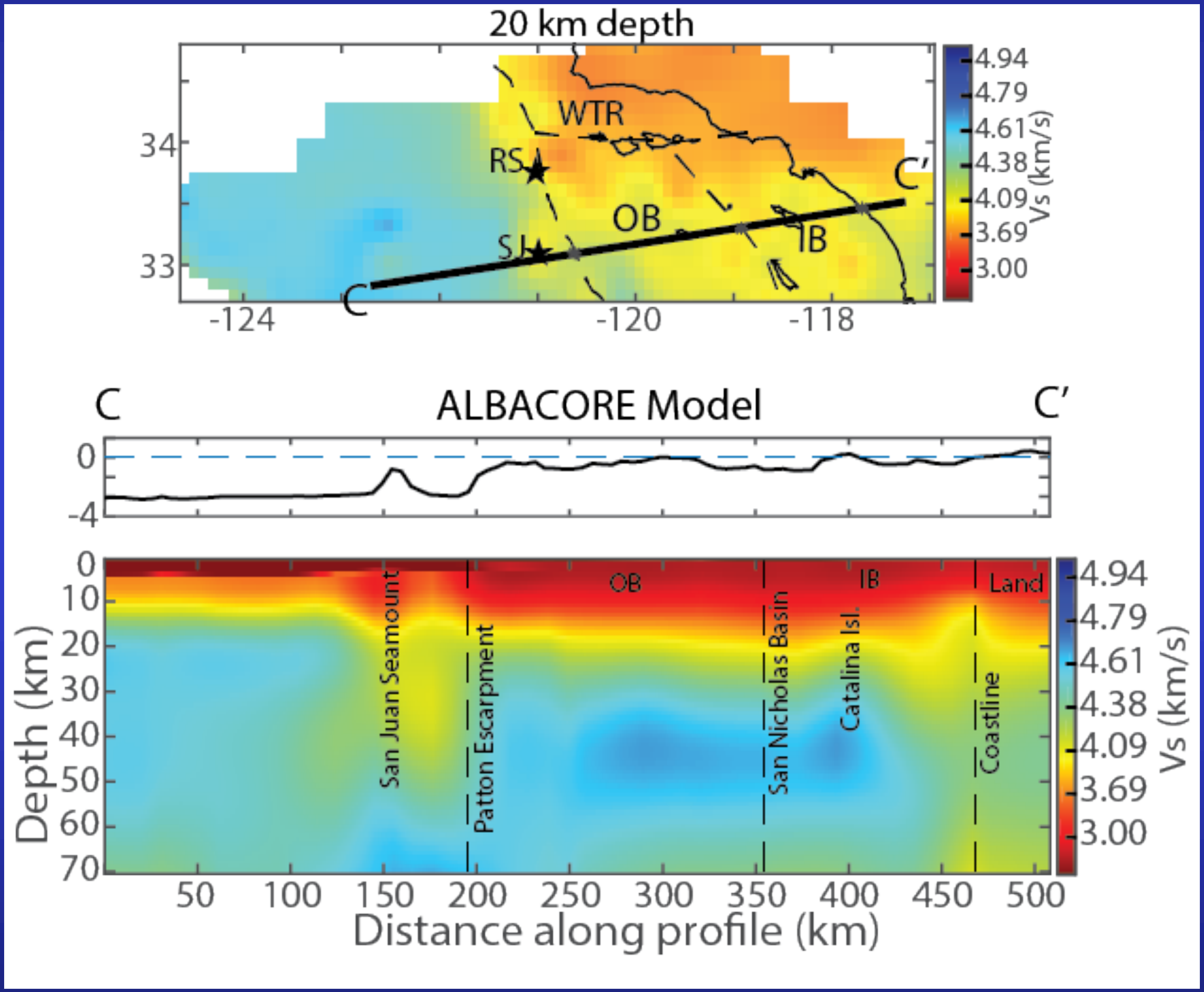








Shear-wave velocity model: C-C′



WTR: Western Transverse Ranges

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RS: Rodriguez Seamount

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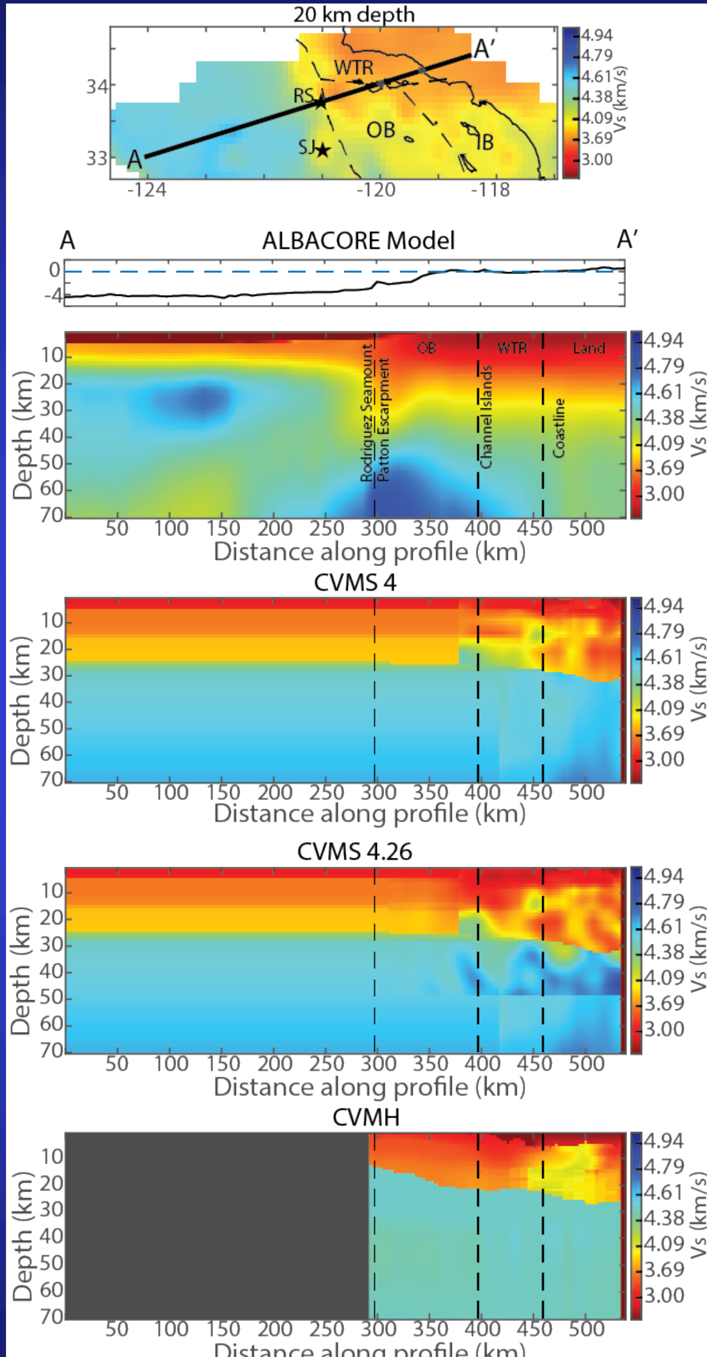
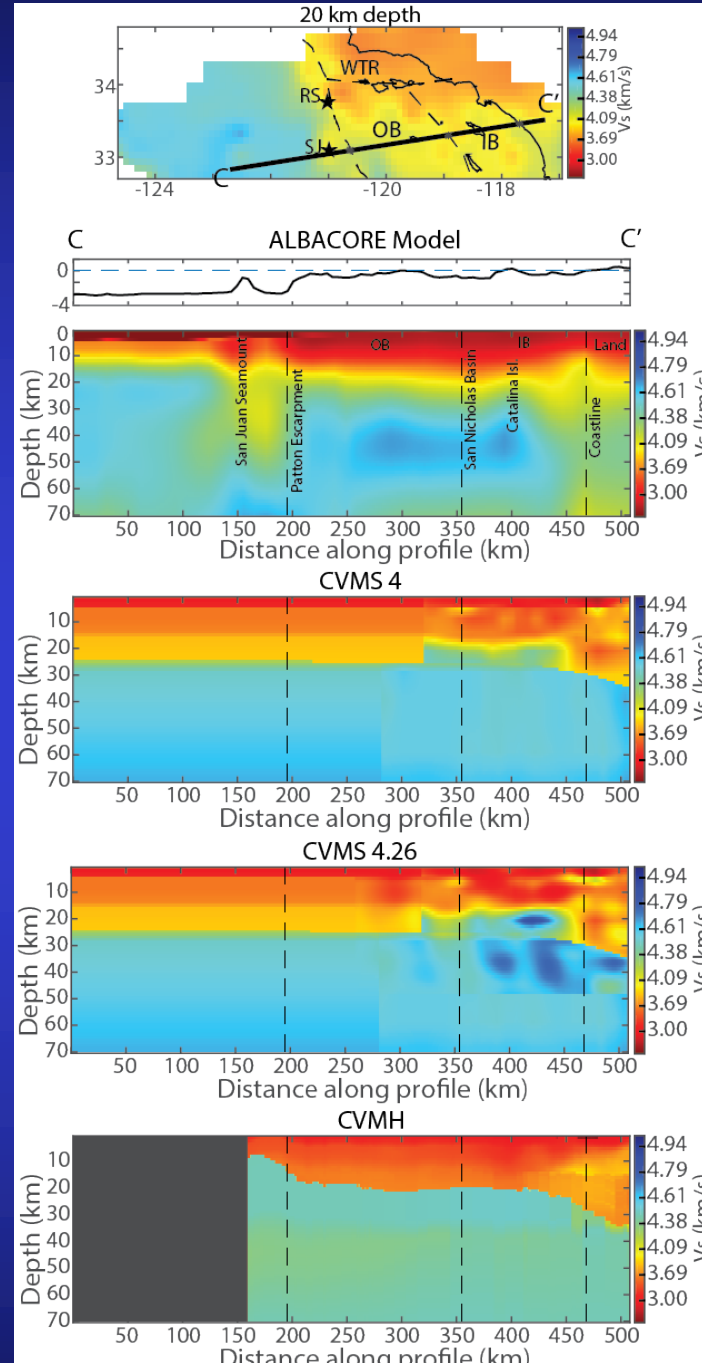
Bowden et al., JGR, 2016

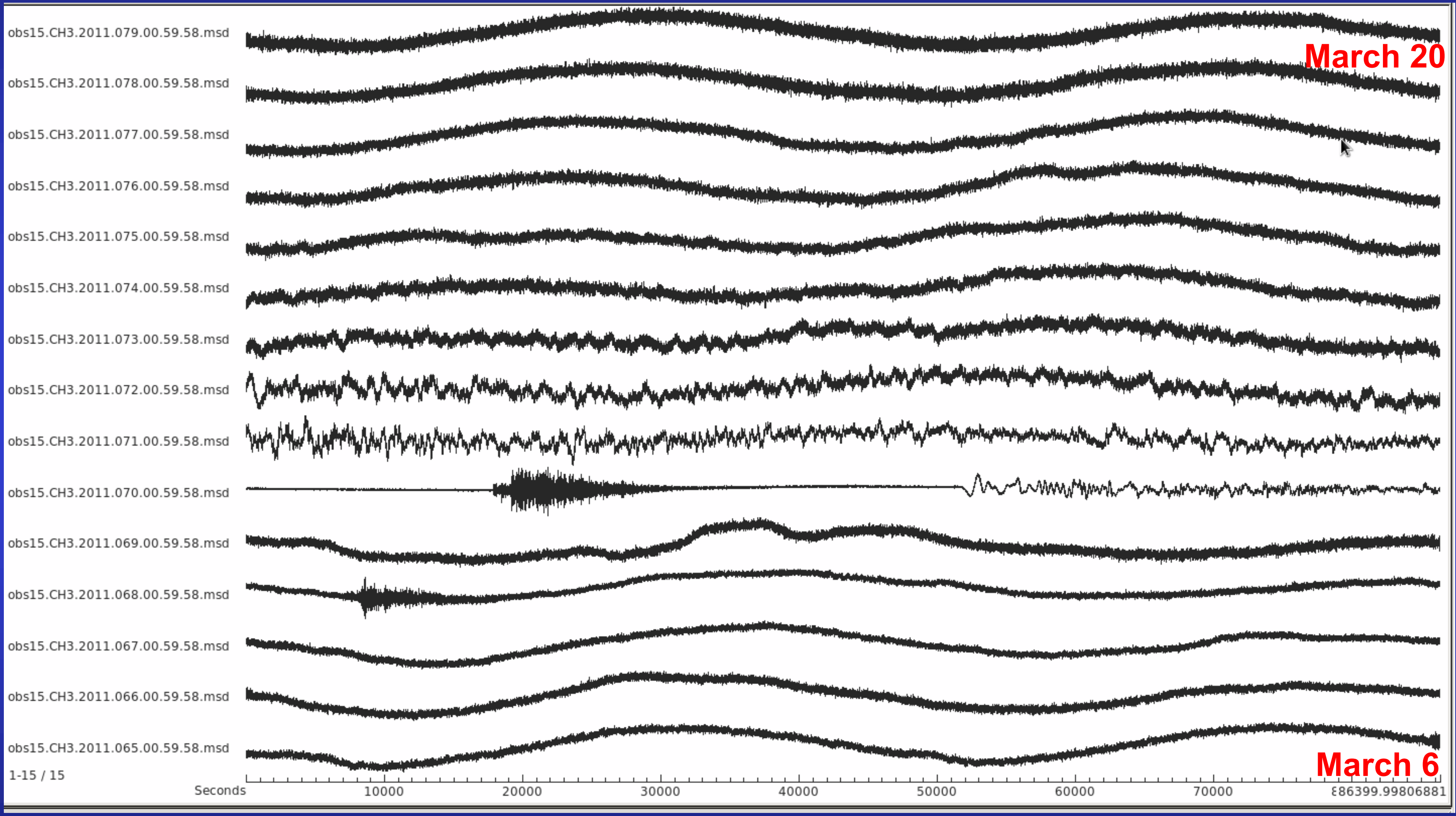

20 km depth
A
A′
WTR
RS
OB
SJ
IB
34
33
-124
-120
-118
4.94
4.79
4.61
4.38
4.09
3.69
3.00
Vs (km/s)
ALBACORE Model
0
-4
Rodriguez Seamount
Patton Escarpment
Channel Islands
Coastline
WTR
Land
Depth (km)
Distance along profile (km)
CVMS 4
CVMS 4.26
CVMH


20 km depth
C
C′
WTR
RS
OB
SJ
IB
34
33
-124
-120
-118
4.94
4.79
4.61
4.38
4.09
3.69
3.00
Vs (km/s)
ALBACORE Model
0
-4
San Juan Seamount
Patton Escarpment
San Nicholas Basin
Catalina Isl.
Coastline
OB
IB
Land
Depth (km)
Distance along profile (km)
CVMS 4
CVMS 4.26
CVMH

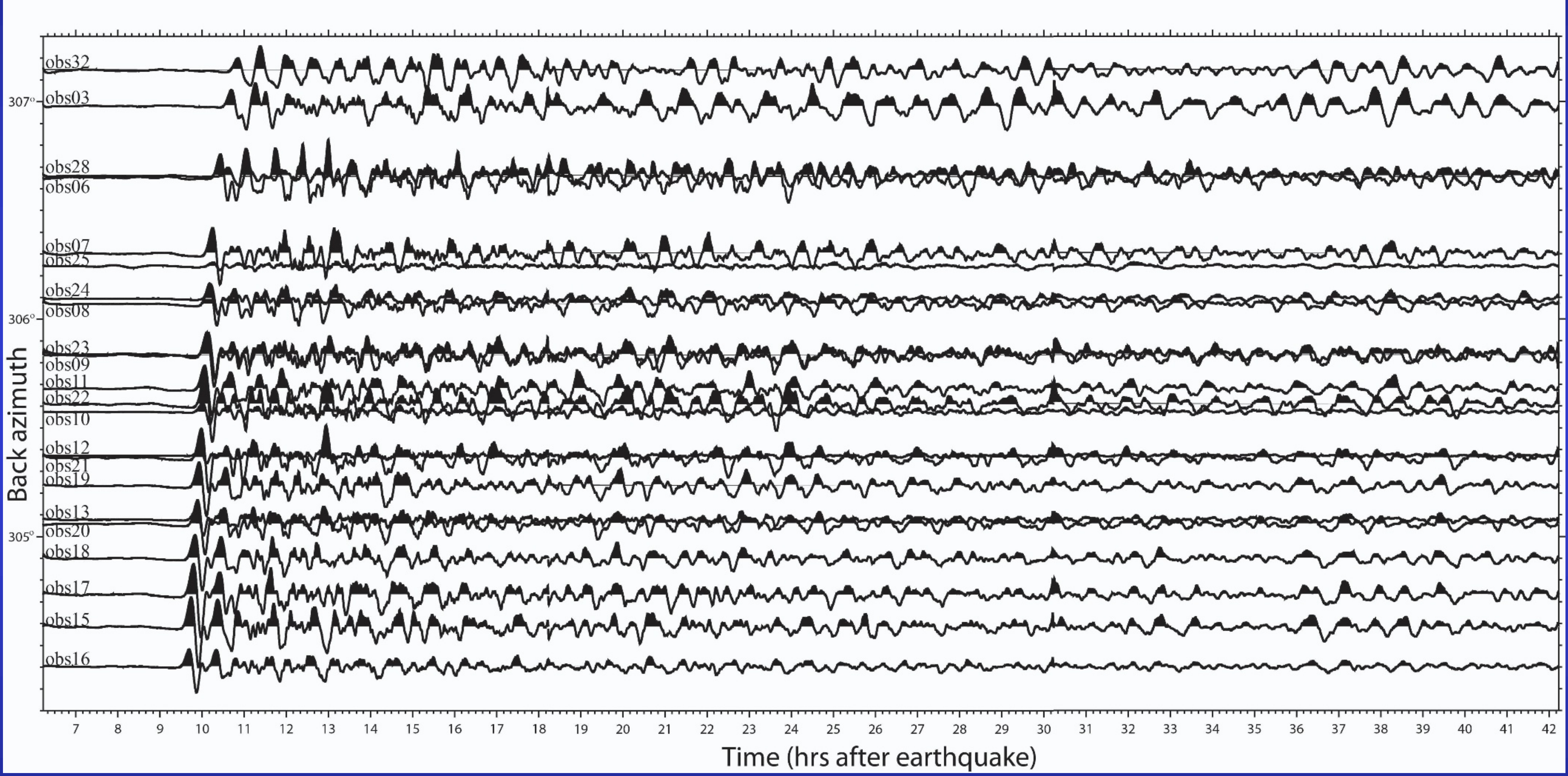
Interpretations

- Variations in Moho depth within Inner Borderland, Outer Borderland, and especially at Patton Escarpment.
- No evidence of a westward extension of the high-velocity anomaly underlying the WTR.
- No evidence for continuous, underplated Farallon slab.
- Patton Escarpment doesn’t look like a former subduction zone. Low velocities in the uppermost mantle near the Patton Escarpment correlate spatially with seamounts which are remnants of spreading processes along the East Pacific Rise spreading center.

Differential Pressure Gauge waveforms March 6-20, 2011 from a deep-water OBS



March 2011 Tohoku tsunami recorded on ALBACORE stations



Goals:

- Identify scatterers that contributed to subsequent coherent phases arriving after first tsunami arrival.
- Use findings in the development of next-generation tsunami warning messages that more clearly identify time-varying, location-specific hazard threat.

Differential Pressure Gauge

- Currents from oceanographic signals (ocean wave, boundary currents, eddies, etc.)
- ~2000 seconds to a few Hz (hydrophone: ~1 Hz to >100 Hz.
- Tides
- Seafloor compliance
- Tsunamis
- Infragravity waves
- Slow slip, Rayleigh waves
- Seafloor Geodesy

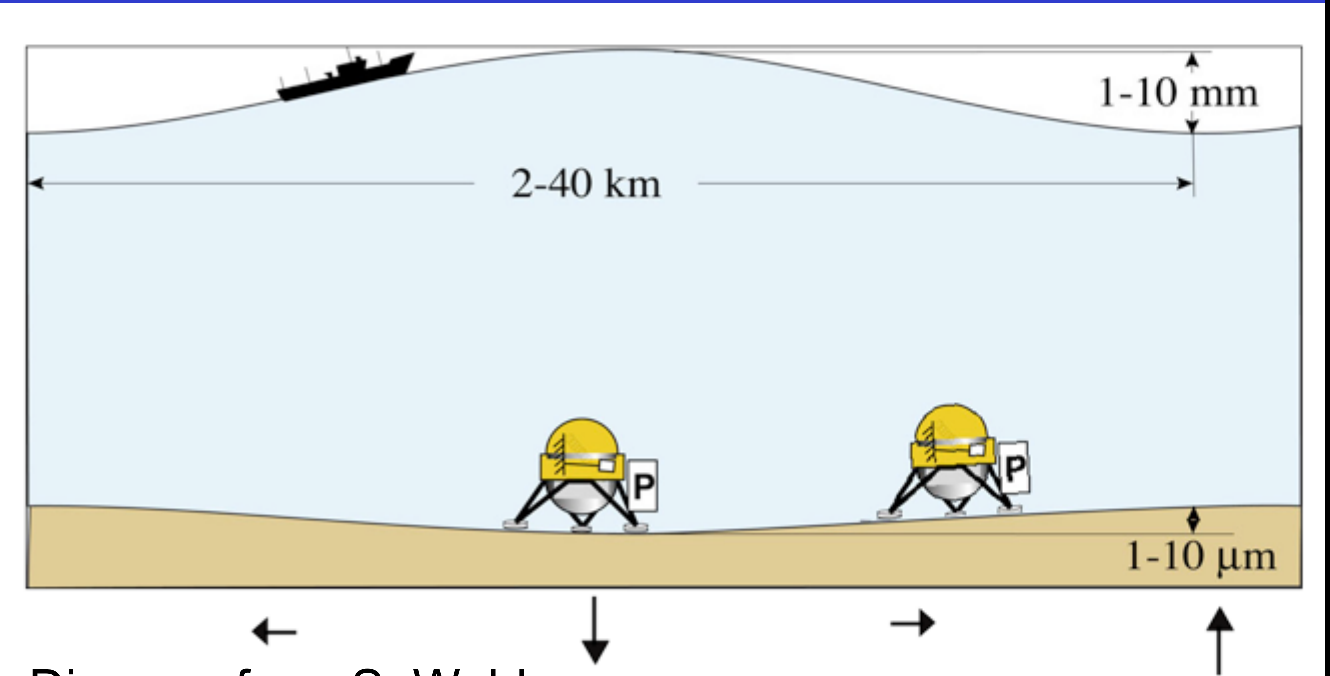
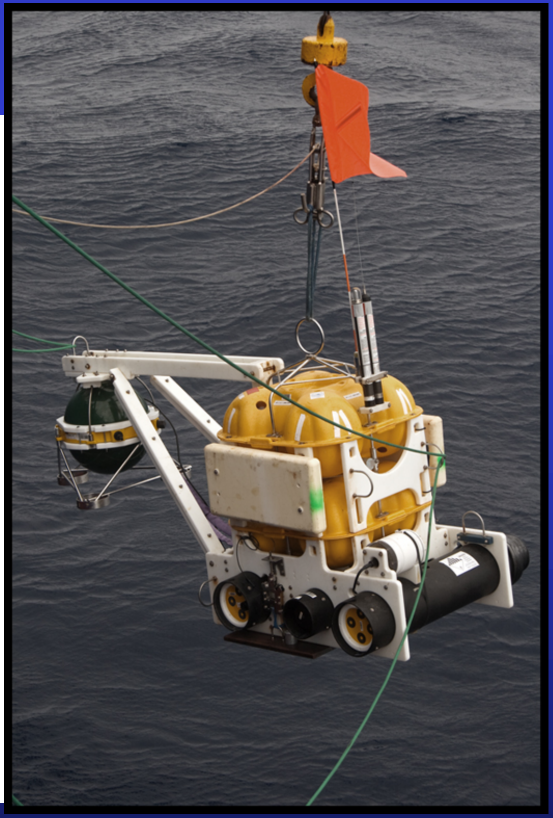
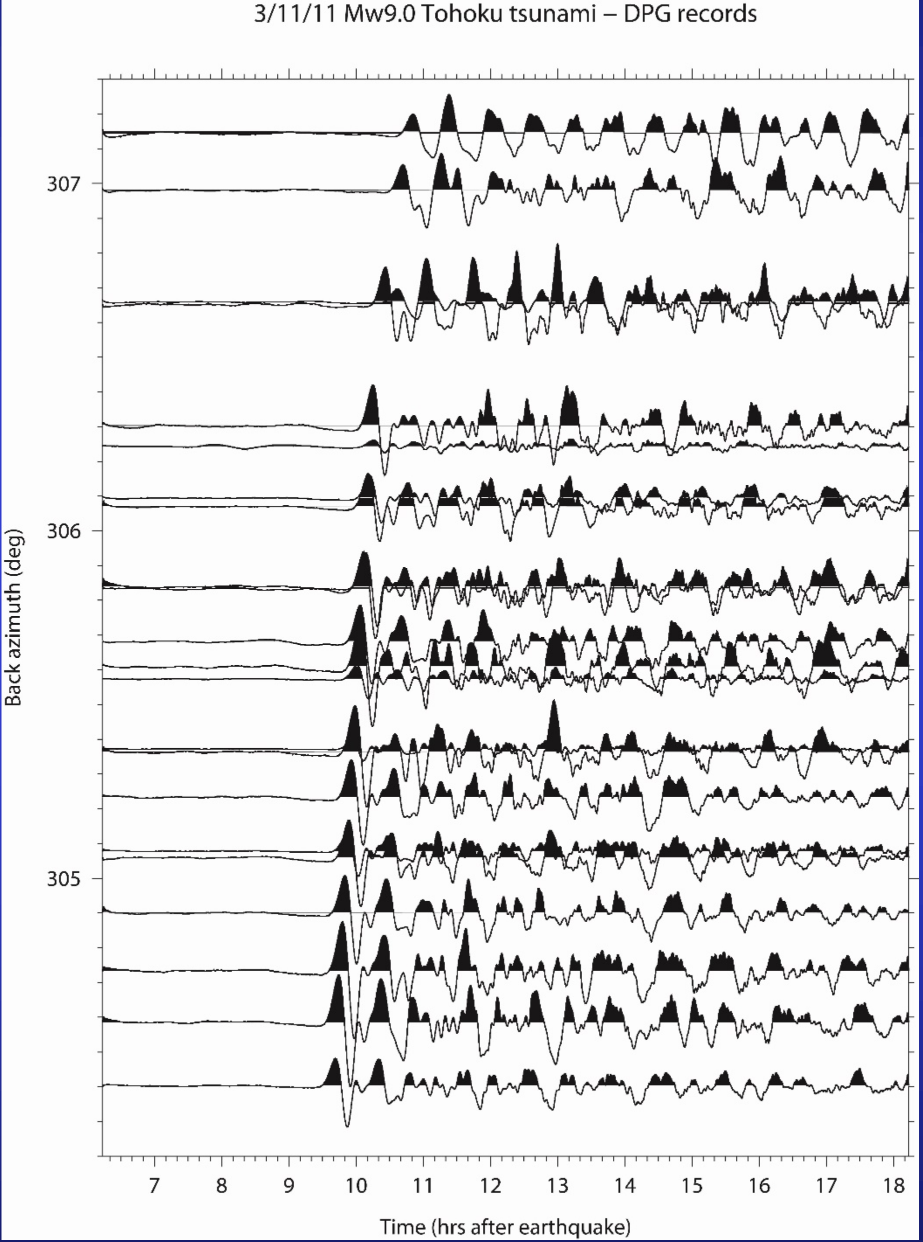
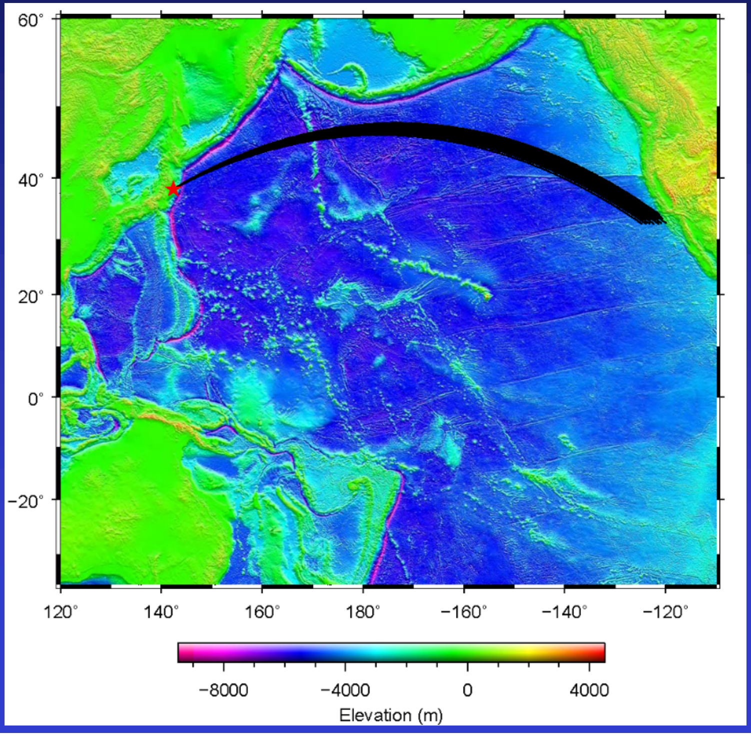


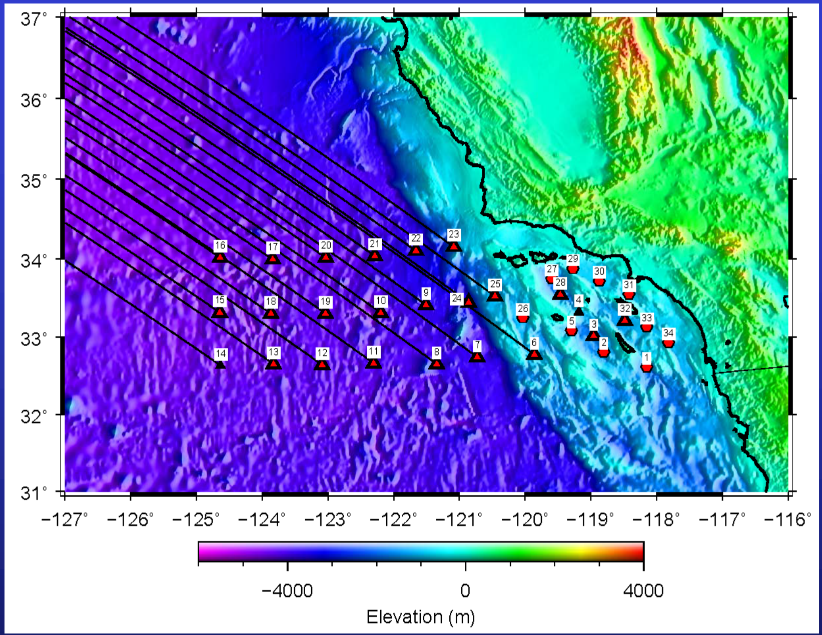
Diagram from S. Webb



March 2011 Tohoku tsunami recorded on ALBACORE stations

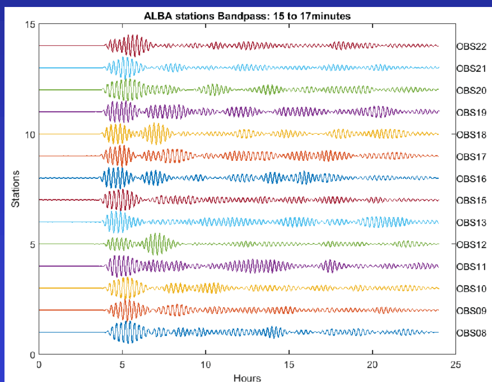






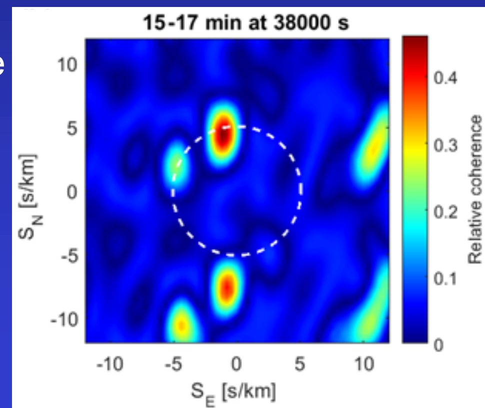
Direction of arrival of later-arriving, large-amplitude phases

15-17 min



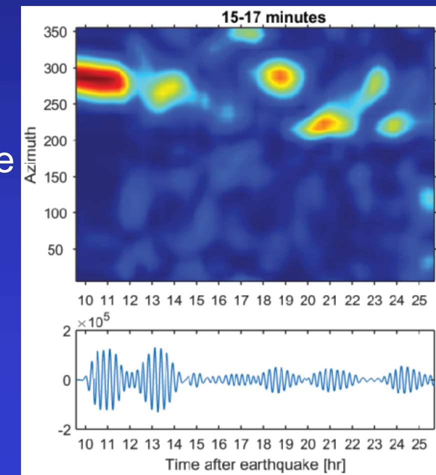
Coherence stacking

after filtering

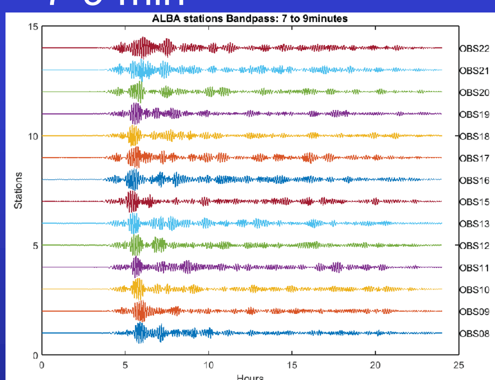


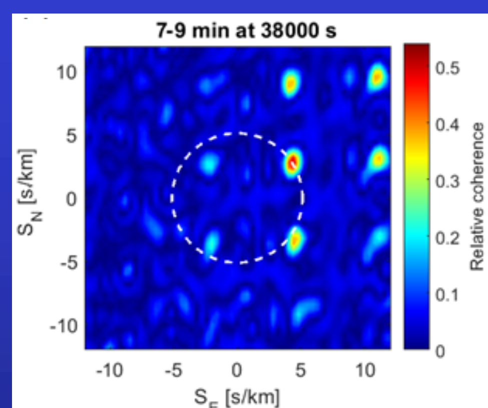
Azimuthal dependence

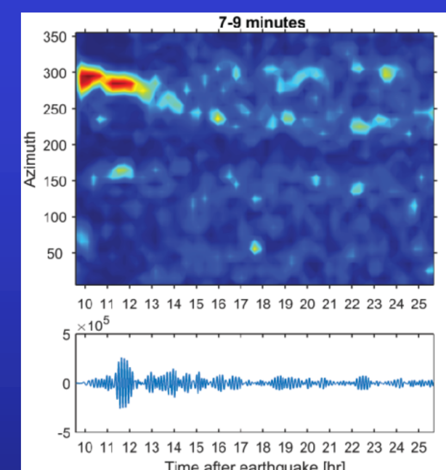
after removing spatial aliasing



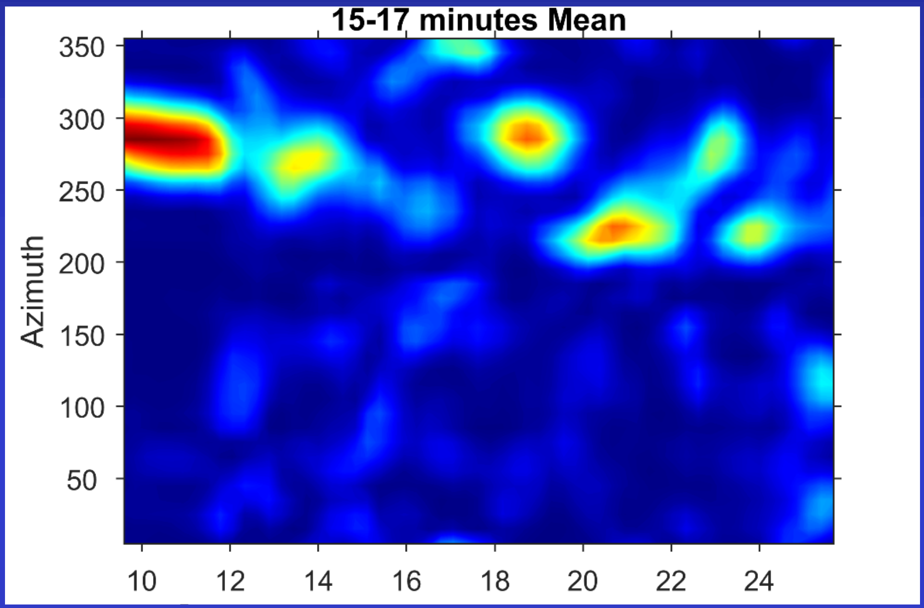
7-9 min

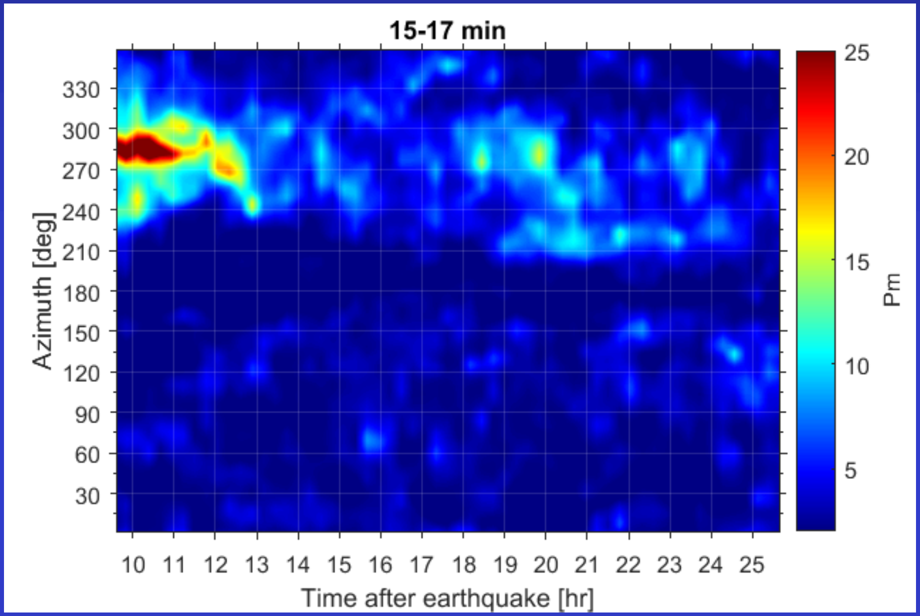






Effect of MUltiple SIgnal Classification method to estimate/refine direction of arrival



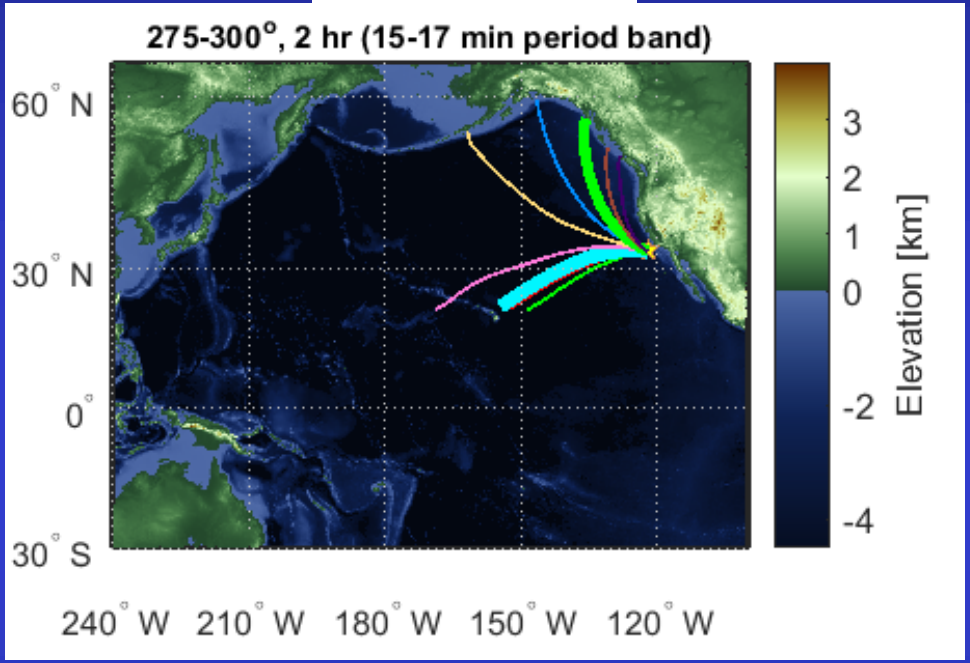


Conventional beamforming

Application of MUltiple SIgnal Classification

Scattering sources of later-arriving, large-amplitude phases: back-projection

1-2 hrs after initial arrival

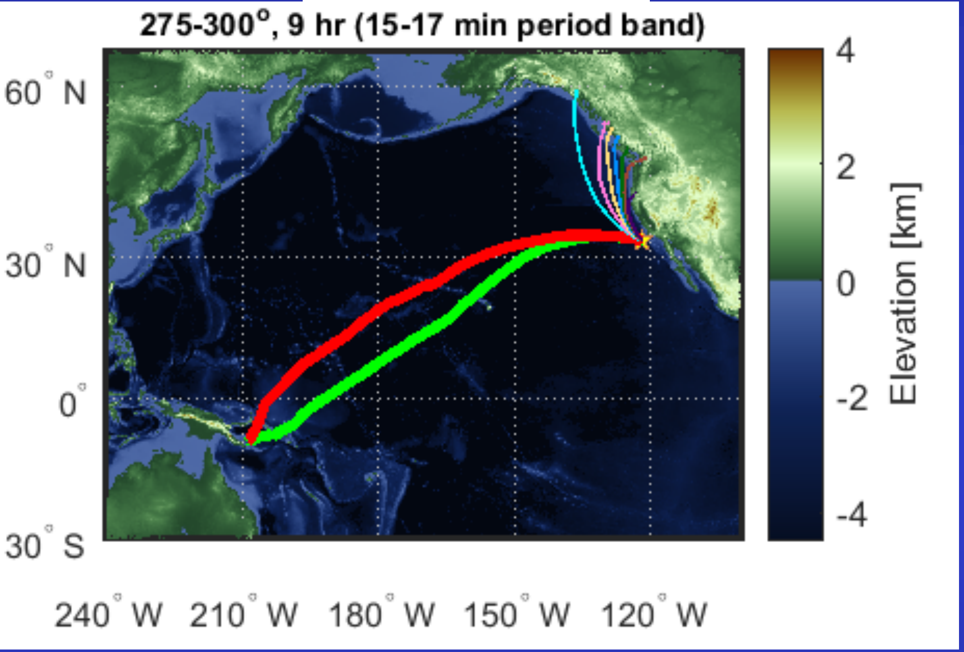


- 275°-300° back-azimuth range.
- Possible scattering source: Hawaiian Island chain and/or SE Alaskan coastline.

Shi et al.., 16WCEE, 2016

Scattering sources of later-arriving, large-amplitude phases: back-projection

8-9 hrs after initial arrival

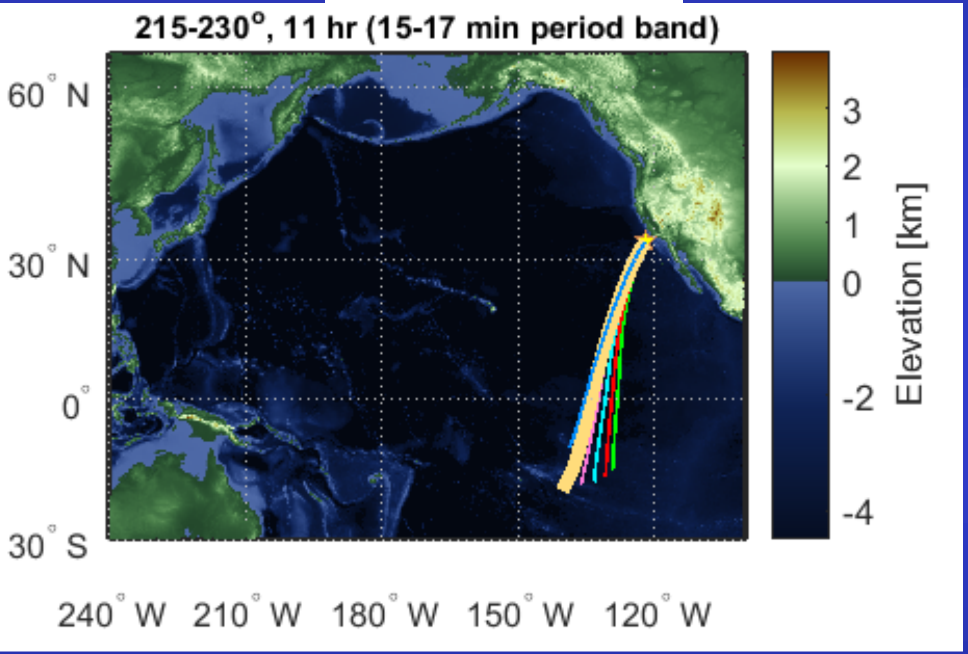


- 275°-300° back-azimuth range.
- Possible scattering source: Papua New Guinea region.

Shi et al.., 16WCEE, 2016

Scattering sources of later-arriving, large-amplitude phases: back-projection

10-11 hrs after initial arrival



- 215°-230° back azimuth range.
- Possible scattering source: French Polynesia region.

Shi et al.., 16WCEE, 2016


ACKNOWLEDGMENTS:
Scripps Institution of Oceanography OBS Instrument Pool Engineers
UNOLS/ Scripps Institution of Oceanography Marine Facility
(captain & crew of R/V Melville and R/V New Horizon)

Shi, J., M. D. Kohler, J. N. Sutton, and J-P Ampuero, Mapping coherent, time-varying wavefronts from the 2011 Tohoku tsunami into enhanced, time-dependent warning messages, *16th World Conference on Earthquake Engineering (16WCEE*), Santiago, Chile (January 2017), submitted, 2016.

Ramsay, J., M. D. Kohler, P. M. Davis, X. Wang, W. Holt, D. S. Weeraratne, Anisotropy from SKS splitting across the Pacific-North America plate boundary offshore southern California, *Geophys. J. Int.*, 2016.

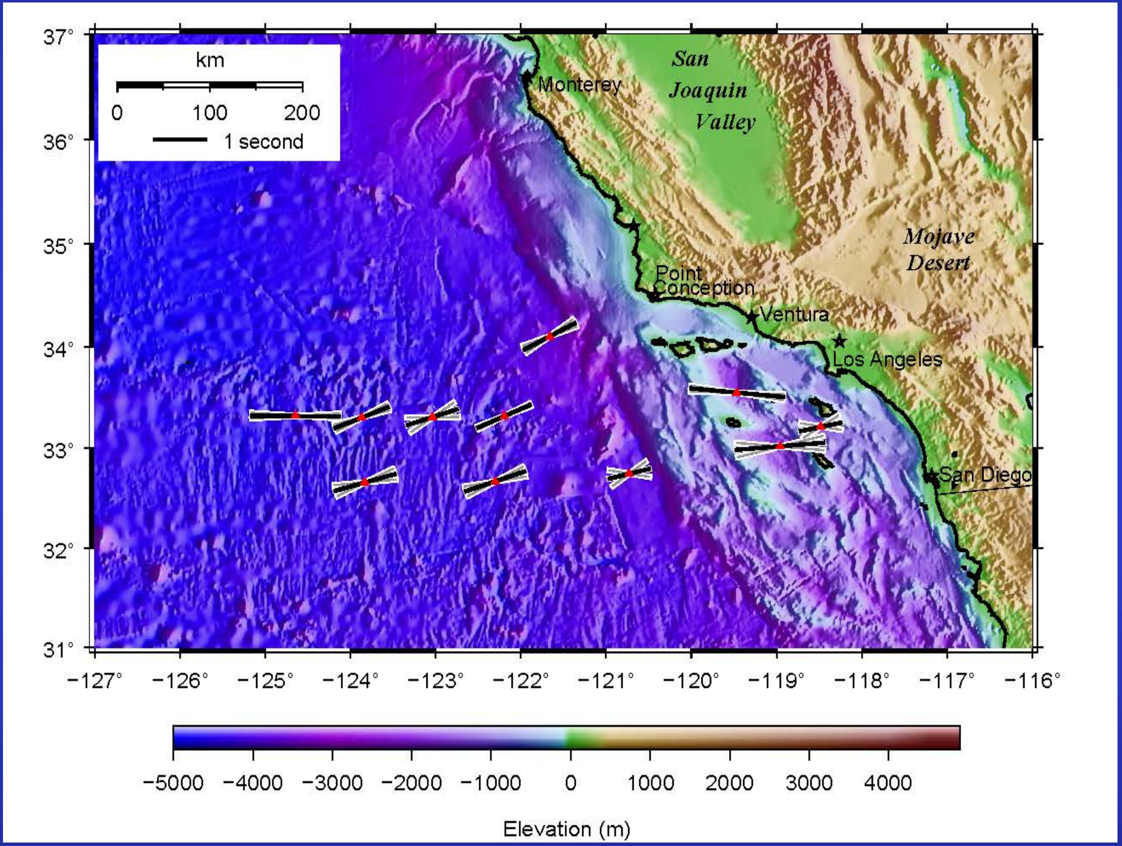
Bowden, D. C, M. D. Kohler, V. C. Tsai, and D. S. Weeraratne, Offshore Southern California lithospheric velocity structure from noise cross-correlation functions, *J. Geophys. Res*., 2016.

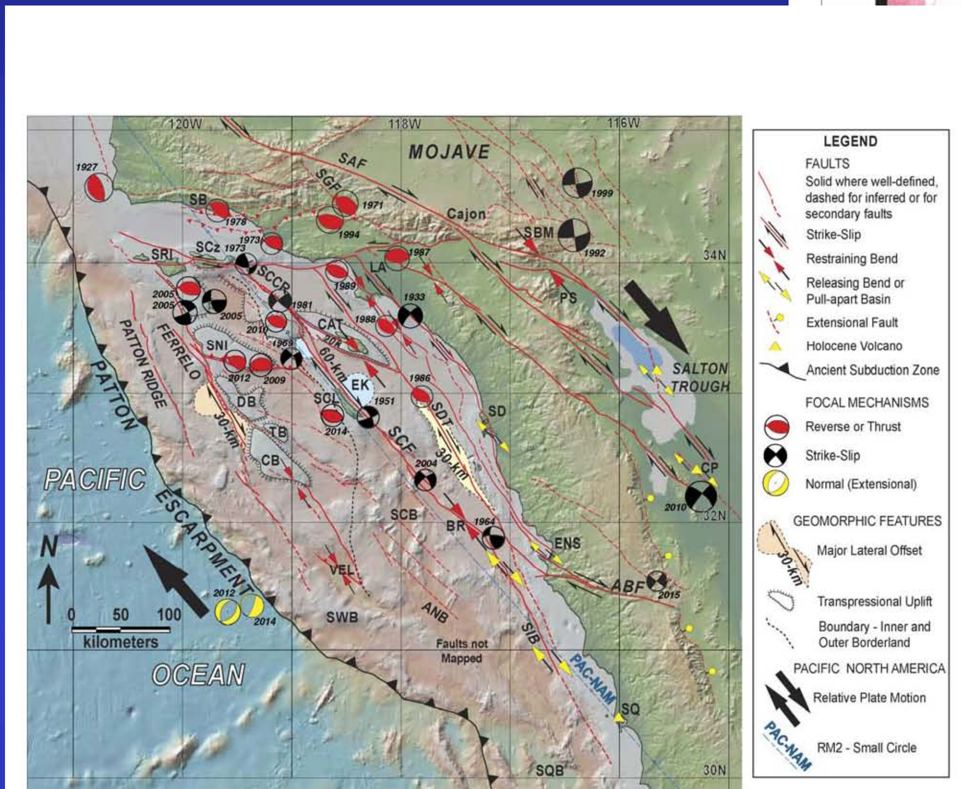
Lin, F-C., M. D. Kohler, P. Lynett, A. Ayca, and D. Weeraratne, The March 11, 2011 Tohoku tsunami wavefront mapping across offshore southern California, *J. Geophys. Res.*, 2015.

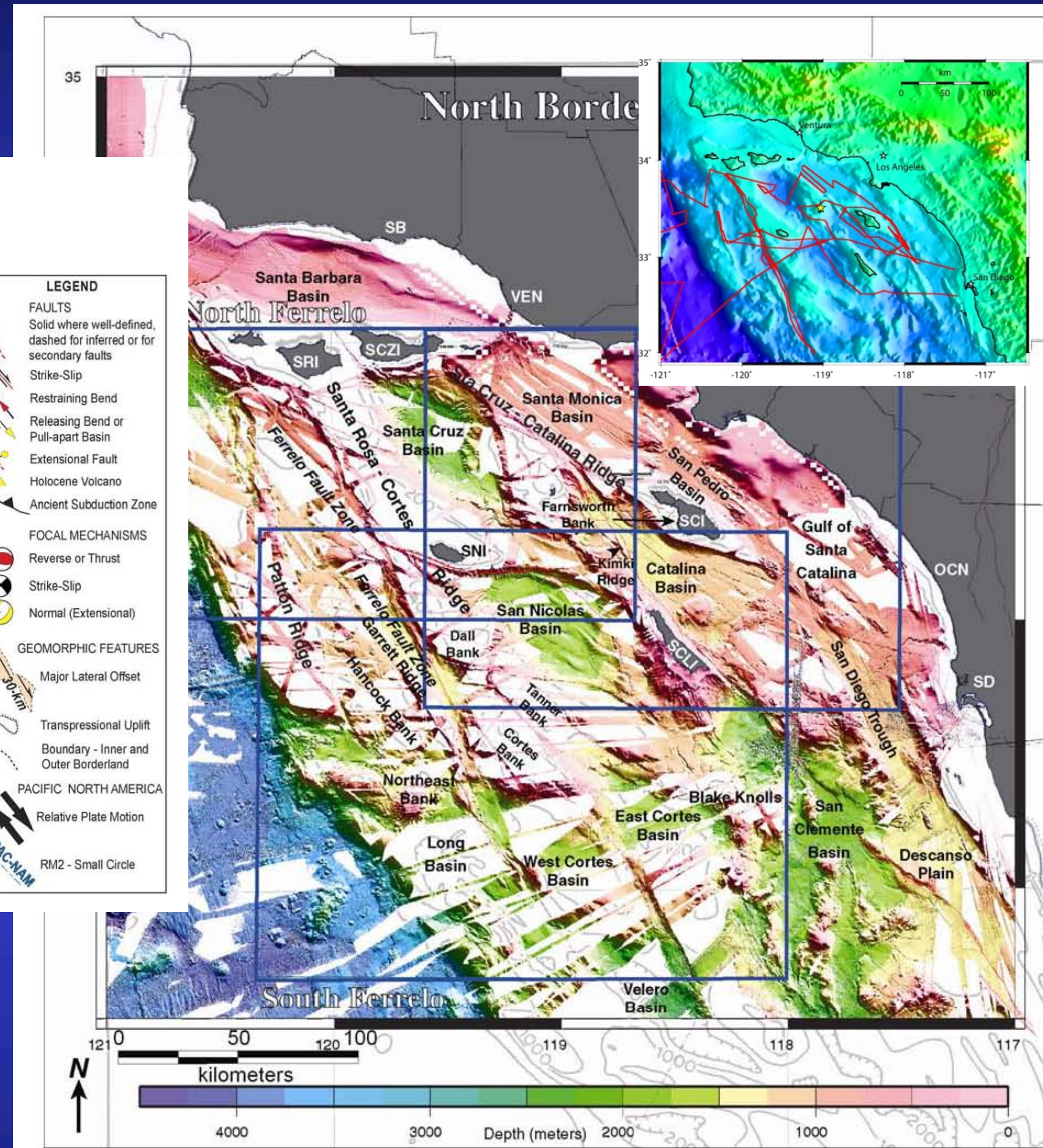
Legg, M. R., M. D. Kohler, N. Shintaku, and D. S. Weeraratne, High-resolution mapping of two large-scale transpressional fault zones in the California Continental Borderland: Santa Cruz-Catalina Ridge and Ferrelo faults*, J. Geophys. Res.*, *120*, 915–942, 2015.

Reeves, Z., V. Lekic, N. Schmerr, M. D. Kohler, and D. Weeraratne, Lithospheric structure across the continental borderland from receiver functions, *Geochemistry, Geophysics, Geosystems*, 2015.

Stacked SKS splitting results







Study that combined new ALBACORE multibeam data with existing ship track data (Legg et al., JGR, 2015)