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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• 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

CVMS 4 (Magistrale et al., 2000)

CVMS 4.26 (Lee et al., 2014)

CVMH (Shaw et al., 2015)
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.
- 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-asthenosphere interface geometry from receiver functions.
- Offshore hypocenters, seismicity patterns, fault geometries.
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.
Wave loading correction using pressure gauge waveforms

**Raw Z-component**

**LDH (Differential Pressure Gauge)**

**Without Corrections:**
8 Second Period

**With Corrections:**
8 Second Period

**Fundamental**

**First Overtone**
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

Checker in

Checker out
Shear-wave velocity model: C-C’

WTR: Western Transverse Ranges
IB: Inner Borderland
OB: Outer Borderland
RS: Rodriguez Seamount
SJ: San Juan Seamount

Bowden et al., JGR, 2016
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

Coherence stacking after filtering
Effect of MUltiple Slignal Classification method to estimate/refine direction of arrival

Conventional beamforming

Application of MUltiple Slignal 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

- 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

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