Shear wave splitting observations across the Juan de Fuca plate system: Ridge-to-trench constraints on mantle flow from 2 years of Cascadia Initiative OBS data

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Data & Methods

The CI dataset includes measurements from the Juan de Fuca (JdF), and Gorda ridges, the young and melting asthenosphere lithosphere–asthenosphere transition zone of the Juan de Fuca transform, Mendocino triple junction, and the Cascadia subduction zone. Models of upper mantle flow are sensitive to tectonic environments, and since we do not have time-lapse data, we choose to analyze our data in zoned subsets (pictured below).

Data & Quality

Measurements from 116 OBS and 5 TA stations. OBS recorded average of 3 usable measurements with only 15 stations recording a single measurement. Backazimuthal distribution of events (pictured right).

Year 2 data recorded several exceptionally clear events.

Method for OBS

We used SplitP [2] to measure splitting parameters. Due to high noise levels, traditional methods must be evaluated and modified.

Filtering

Filter at 0.06-0.1 Hz initially. Filter is varied between 0.2-0.15 Hz. Check for stability and allow as much high frequency data as possible [3].

Validity of 3 splitting methods

The Silver & Chan (SC), Rotation Correlation (RC), and Eigenvalue (EV) all reach similar frequency limits. RC has been found to perform poorly in low SNR conditions [4]. Only report SC method but still use RC and EV for quality control.

Results

The Juan de Fuca plate interior

| Fast-axis orientations closely follow APM Spots >60° from ridge perpendicular |

The Cascadia Subduction Zone

| North CSZ trench perpendicular Rotation towards trench parallel in Northern Oregon South CSZ trench perpendicular Onshore dominantly trench perpendicular |

The Mendocino triple junction and southern Gorda

| N-S Compressional region (applied left) Interaction of weak Gorda plate and Pacific plate motion (picturred bottom left) | Mendocino triple junction and southern Gorda |

Mendocino triple junction and southern Gorda

Gorda interior and nearby Pacific coherent MTW Significantly different from JdF APM. Corresponds with Pacific APM and Gorda ridge spreading direction. MTW is more complex and displays large variance.

The Blanco Transform

Near the Blanco (~28 km from the transform) orientations parallel the boundary. At the Mendocino triple junction, orientations begin to rotate towards APM direction. Possible influence from transform is seen in the distance needed to transition to APM.

Discussion & Interpretation

The Juan de Fuca plate interior

- Frozen anisotropy in the lithosphere from corner flow at the JdF ridge. Fast axis should align with the spreading direction, which we do not observe. While this signal could exist, it is not the dominate signal.
- Ambient mantle flow. Ambient flow is in the W-E direction due to Farallon subduction. This signal is strong enough to dominate the JdF if it also dominates signals on the Pacific plate and at the ridge ridge.
- Strain induced by JdF APM (right). There is great agreement between fast-axis orientation and APM. Previous OBS studies found similar observations (Pacific/Nazca [5] and New Zealand [7]).

The Mendocino triple junction and southern Gorda

- 3D flow due to MTJ tectonics. Several proposed models describe asthenospheric flow near MTJ (solid flow [6], fluid core [4], stagnant splinting [11], stagnant splitting [4]). All models are not correct (11). None of these models can account for flow as we see at the Gorda ridge.
- Ambient mantle flow. Ambient flow is W-E and could be funneling into the lithosphere. If ambient flow dominates, its influence should be seen over the entire JdF ridge region. Measurements matching APM and the variable spots at the JdF ridge appear to contradictory this.

The Blanco Transform

- Lithospheric deformation. Strong agreement near the transform with relative plate motion. Comparison of rupture locations and isofrequency contours (picturred below) constrain the lithosphere to <22 km but smallest dt values (dt=0.6 s) require >50 km thick layer for 4% anisotropy.
- Anisotropic deformation. Strong agreement with relative plate motion. Rapid changes in orientation are resolvable for anisotropic splitting pattern. The thick layer acts to rotate towards APM direction.
- Upwelling along transform offsets. Asymmetry near the ridge may indicate flow under the upwelling plate in the transform parallel direction. Length of the transform, isobearing splitting patterns, and tomographic images argue against upwelling.

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 Numerical model and simulation of first frequency effects will help constrain models.