# Seismic anisotropy beneath the Juan de Fuca plate system:

## Evidence for hetrogeneous mantle flow

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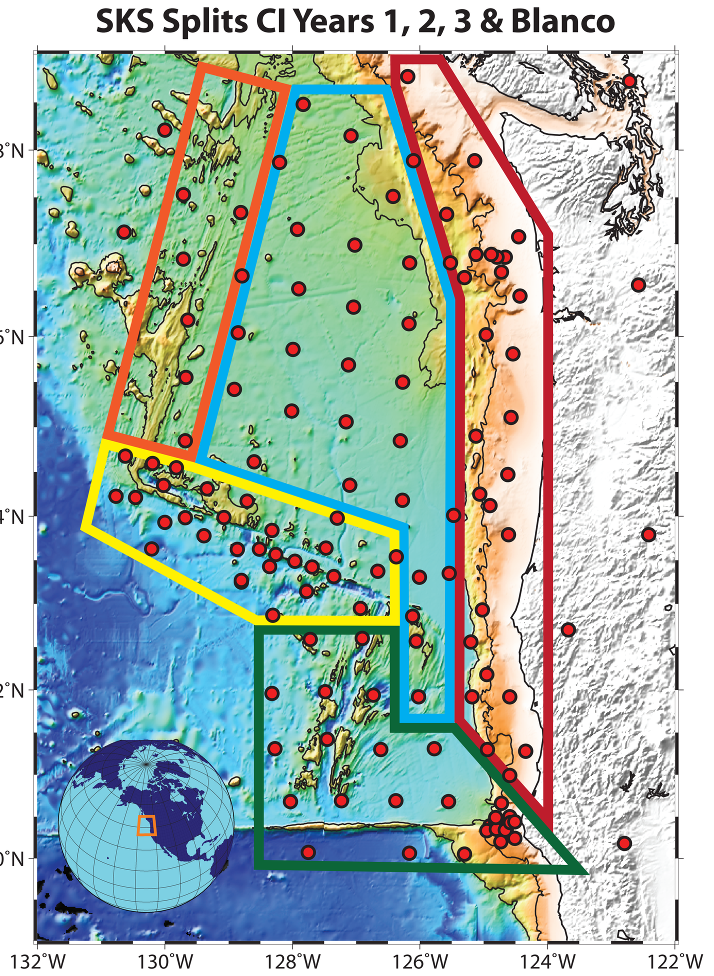
## Data & Methods

The Cascadia Initiative dataset includes several tectonic regions: upwelling beneath the Juan de Fuca (JdF) and Gorda ridges, the young and evolving oceanic lithosphere-asthenosphere system of the plate interior, the Blanco transform, Mendocino triple junction, and the Cascadia subduction zone. Models of upper mantle flow are specific to tectonic environments and, since we are data limited, our single layer analysis will only record first order effects. We choose to analyze our dataset in zoned subsets **(pictured below)**.

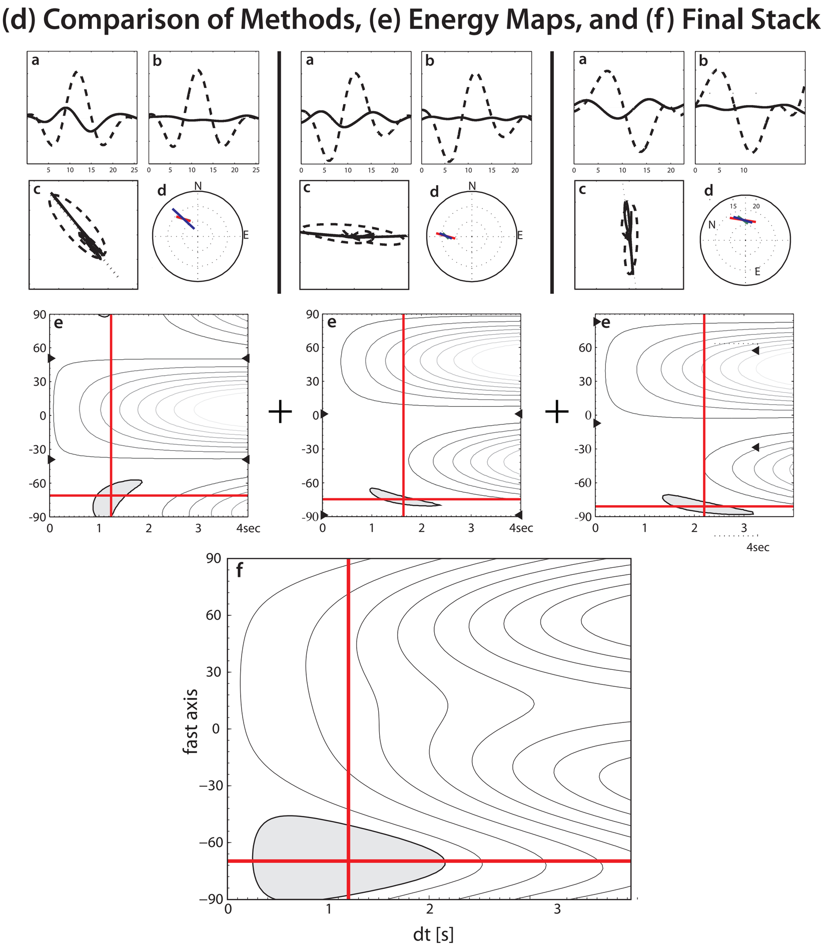
SKS Splits CI Years 1, 2, 3 & Blanco

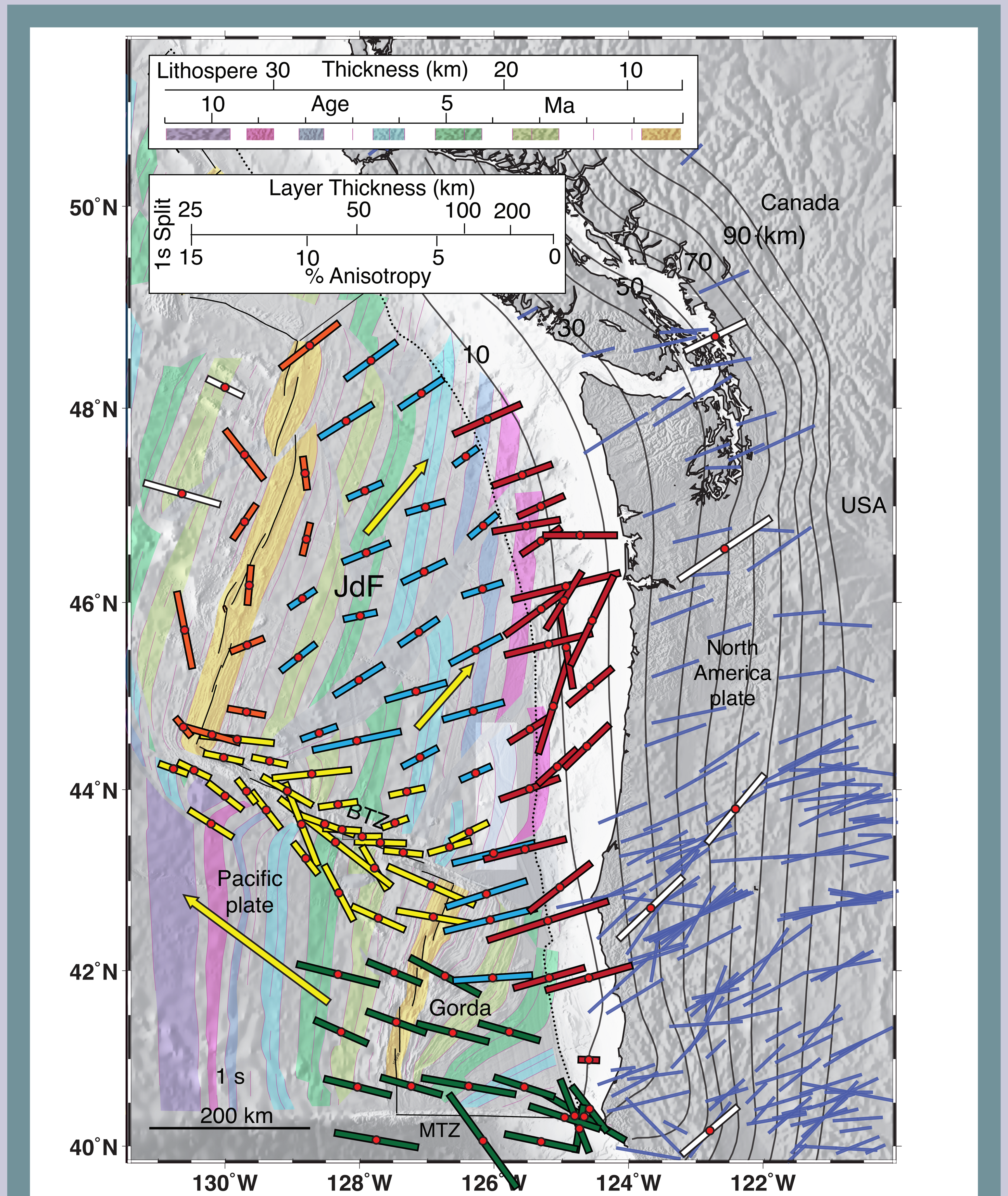



### Data & Quality

Analyzed SKS phases.
111 OBS and 5 TA stations.
OBS recorded average of 4 usable measurements.
Only 14 stations recording a single measurement.
Backazimuthal distribution of events **(pictured bottom right)**.
Year 2 data recorded several exceptionally clear events.

(a) Uncorrected and (b)Corrected Waveforms, (c) Particle Motion, (d) Comparison of Methods, (e) Energy Maps, and (f) Final Stack




### Method for OBS

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

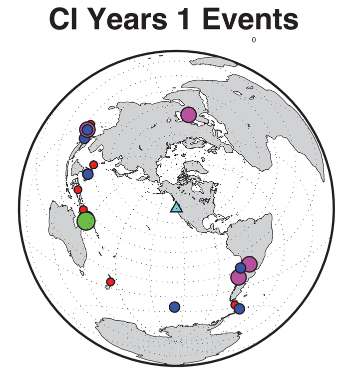
### Filtering

Filter set at 0.03-0.1 Hz initially.
Filter is varied between 0.02-0.15 Hz.
Check for stability and allow as much high frequency data in as possible [3].

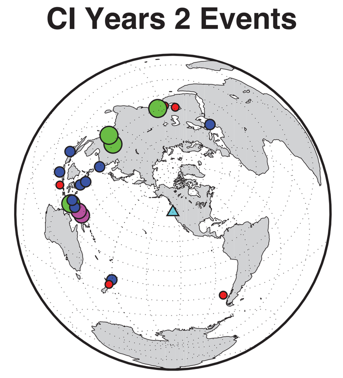
### Validity of 3 splitting methods

The Silver & Chan (SC), Rotation Correlation (RC), and Eigenvalue (EV) all react differently to high noise.
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.

CI Years 1 Events



CI Years 2 Events



### Quality control

Check that SC gives hyperbolic shape and RC appears reasonable.
Discard dt values below 0.5 s (unrealistic at low frequencies) or above 3 s (possible cycle skipping).
EV and SC are compared.

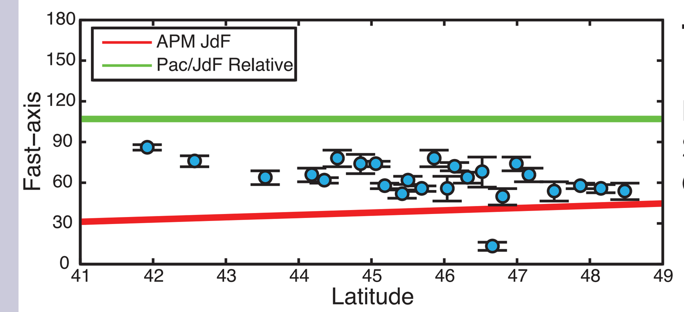
### Stacking

Stacking procedure of Wolfe & Silver [5].
Lowers error estimate and remove false measurements.

### Verification from land sites

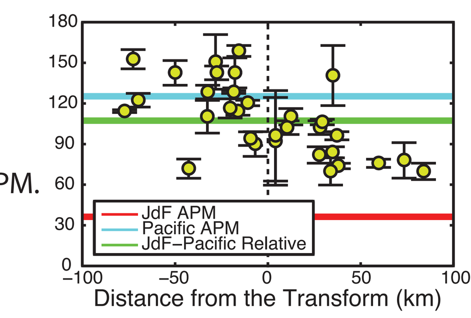
We use this method on 5 land stations.
Verify that reliable splits can be made at these frequencies.
TA stations show excellent agreement with previous studies.

## Results



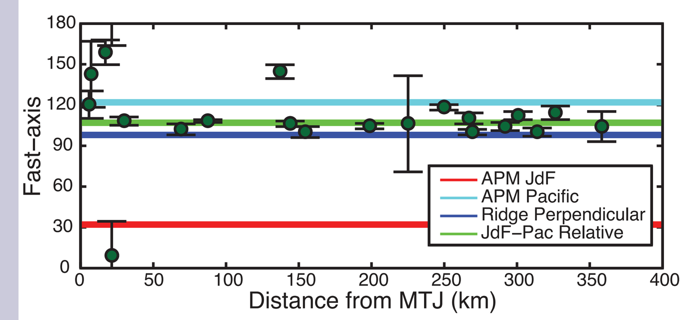

### The Juan de Fuca Plate Interior

Fast-axis orientations broadly follow APM.
Splits ~40° from ridge perpendicular.
Observations are systematically offset CW from APM.



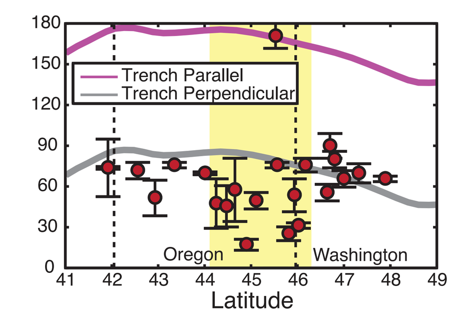

### The Blanco Transform

<20 km from the transform orientations parallel relative motion.
Amay from the transform, orientations rotate towards the respective APM direction.




### Mendocino Triple Junction and Gorda

Gorda interior and nearby Pacific have coherent orientations N109°E.
Significantly different from JdF APM.
Observations fit JdF/Pacific relative motion best.
<25 km from the MTJ displays large local variance.




### The Cascadia Subduction Zone

North CSZ trench perpendicular.
Rotation towards trench parallel in northern Oregon.
South CSZ returns trench perpendicular.
Onshore dominantly trench perpendicular.

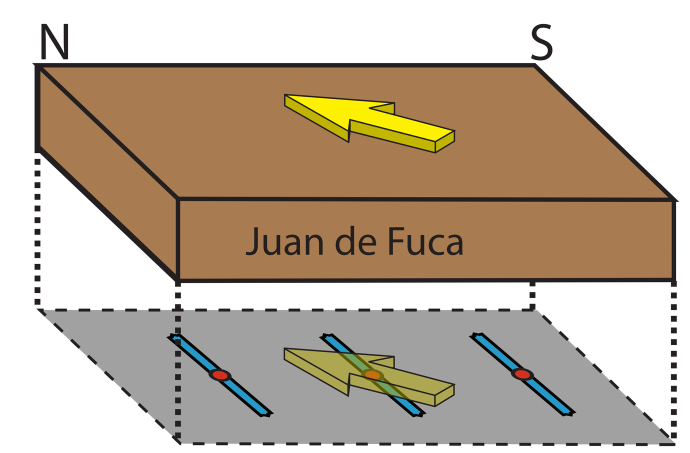
## Discussion & Interpretation

### The Juan de Fuca plate interior

- **Frozen anisotropy in the lithosphere from corner flow at the JdF ridge.** Alignment with the spreading direction is not observe. Splitting times ~1s require a layer too thick to be constrained by the young lithosphere. Possible to explain appernt splitting with two layers.

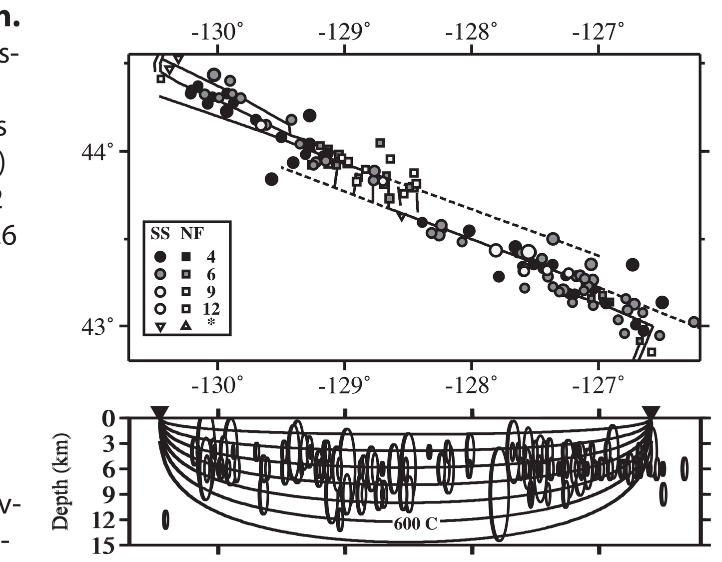
- **Strain induced by JdF APM.** There is broad agreement between fast-axis orientation and APM. Previous OBS studies have found similar observations (Pacific/Nazca [6] and New Zealand [7]. However, observations are systematically offset CW from plate motion.

✔ **Entrained mantle flow (right).** Agreement with APM suggest upper mantle entrainment beneath the plate and into the subduction zone. CW rotation of measurements suggests secondary processes such as a lithospheric contribution or a deep secondary flow. A rotated secondary flow may be consistent with recent plate motion changes and observations of skew at the Endeavour segment.




### The Blanco Transform

- **Lithospheric deformation.** Strong agreement near the transform with relative plate motion. Comparison of rupture locations and isotherms **(pictured below)** constrain the lithosphere to <22 km but smallest dt values (dt=0.6 s) require >50 km thick layer for 4% anisotropy.




[13] Braunmiller & Nablek, 2008

- **Asthenospheric deformation.** Strong agreement with relative plate motion. Rapid changes in orientation are resolvable for anisotropic structure extending near the surface [13]. Requires a low viscosity mantle for such restricted flow.

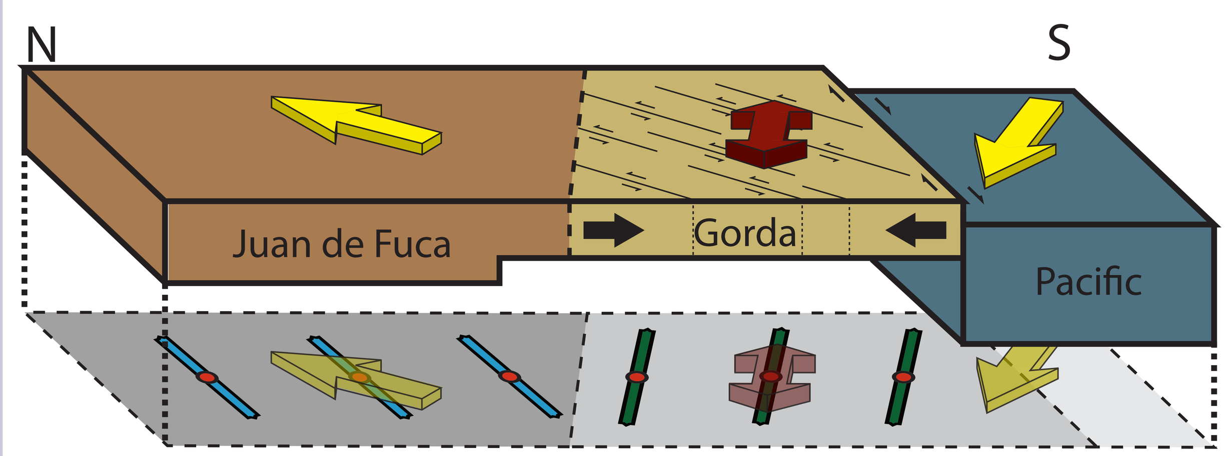
Numerical flow modeling and consideration of finite frequency effects will help constrain models.

### The Mendocino triple junction and southern Gorda

✘ **Toroidal flow.** One popular model to describe asthenospheric flow near MTJ is toroidal flow around the slab edge due to rollback [8] & [9]. We reject this model based on the spacial pattern of splits and the absence of trench parallel orientations.

- **Ambient mantle flow.** Ambient flow is W-E. Deep secondary flow may contribute to skew in the plate interior.

✘ **Strain induced by APM.** Measurements in the southern Gorda do not correlate with APM. Further, the coherent signal is not confined to the Gorda plate.




✘ **Lithospheric signal due to corner flow or crustal deformation.** Anisotropy aligned with the spreading direction are consistent with our results. However, dt =1.2 s and 4% anisotropy requires a 140 km layer, which is much larger than can be expected from corner flow. Faulting due to deformation is all NE-SW trending.

✔ **Broad shear zone due to Pacific/JdF relative motion (pictured bottom left).** Fast-axis orientations correlate well with Pacific/JdF relative motion. The Pacific plate induces a N-S compression in the southern Gorda and facilitates significant deformation. We suggest that the Gorda is a shear zone that accommodates strain induced by relative motion. The upper mantle undergoes reorganization in conjunction with crustal deformation in this diffuse plate boundary.

## References

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