Understanding Seismic Anisotropy Observations in the Context of 3D Slab-induced Flow in Cascadia

UC DAVIS

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Introduction

Existing studies of the Cascadia subduction zone (CSZ) disagree on many aspects of the slab geometry, such as the presence and location of gaps as well as the depth extent.

The CSZ has a relatively low rate of background seismicity, making it difficult to construct high resolution seismic tomographic imagery of the slab.

Seismic anisotropy observations obtained from shear wave splitting (SWS) measurements can be used as a proxy for flow patterns in the upper mantle around the slab.

Direct comparisons between predicted anisotropy from geodynamic models of varying slab geometry with both observed SKS splitting and the velocity flow field may provide new constraints on the slab shape.

Objective: Use temperature (T), pressure (P), and flow velocity from the below six 3D geodynamic models to predict seismic structure of the CSZ and compare to seismic observations.

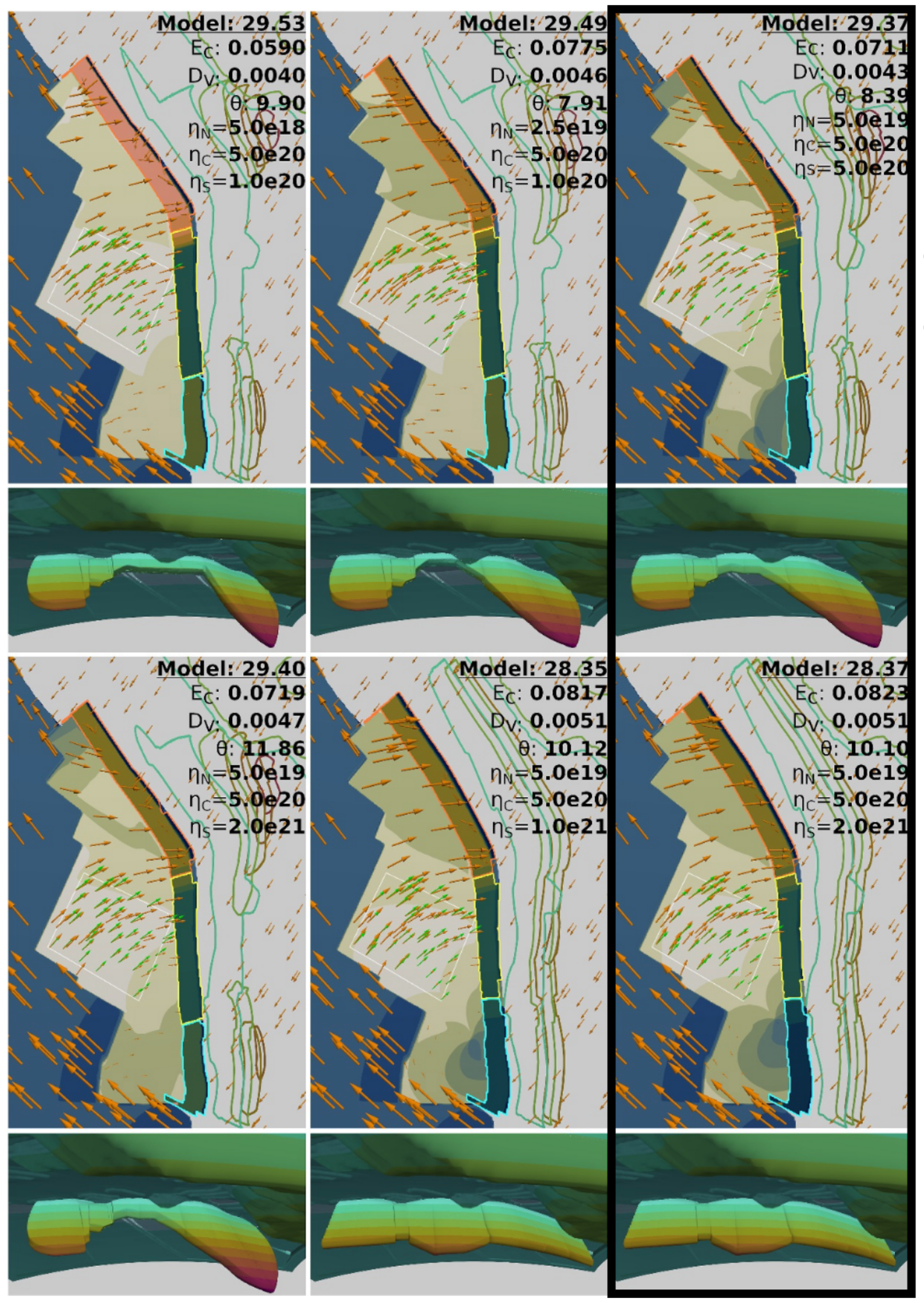


Figure 5, modified from Fraters et al., 2024

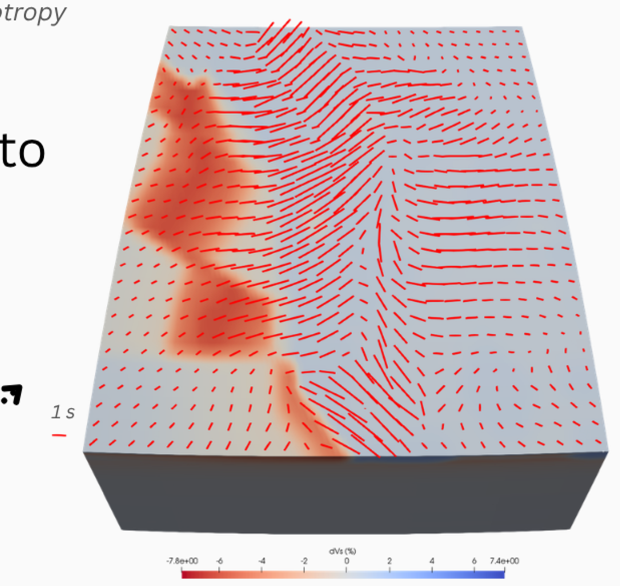
Methods

The workflow relies on the ECOMAN packages developed by Faccenda et al., 2024, an open-source package for geodynamic and seismological modelling of mechanical anisotropy

Full elastic tensor, C_{ijkl}

D-REX_M

Use mantle flow velocity data to calculate the elastic tensor (***C***) that describes the seismic anisotropy (LPO)

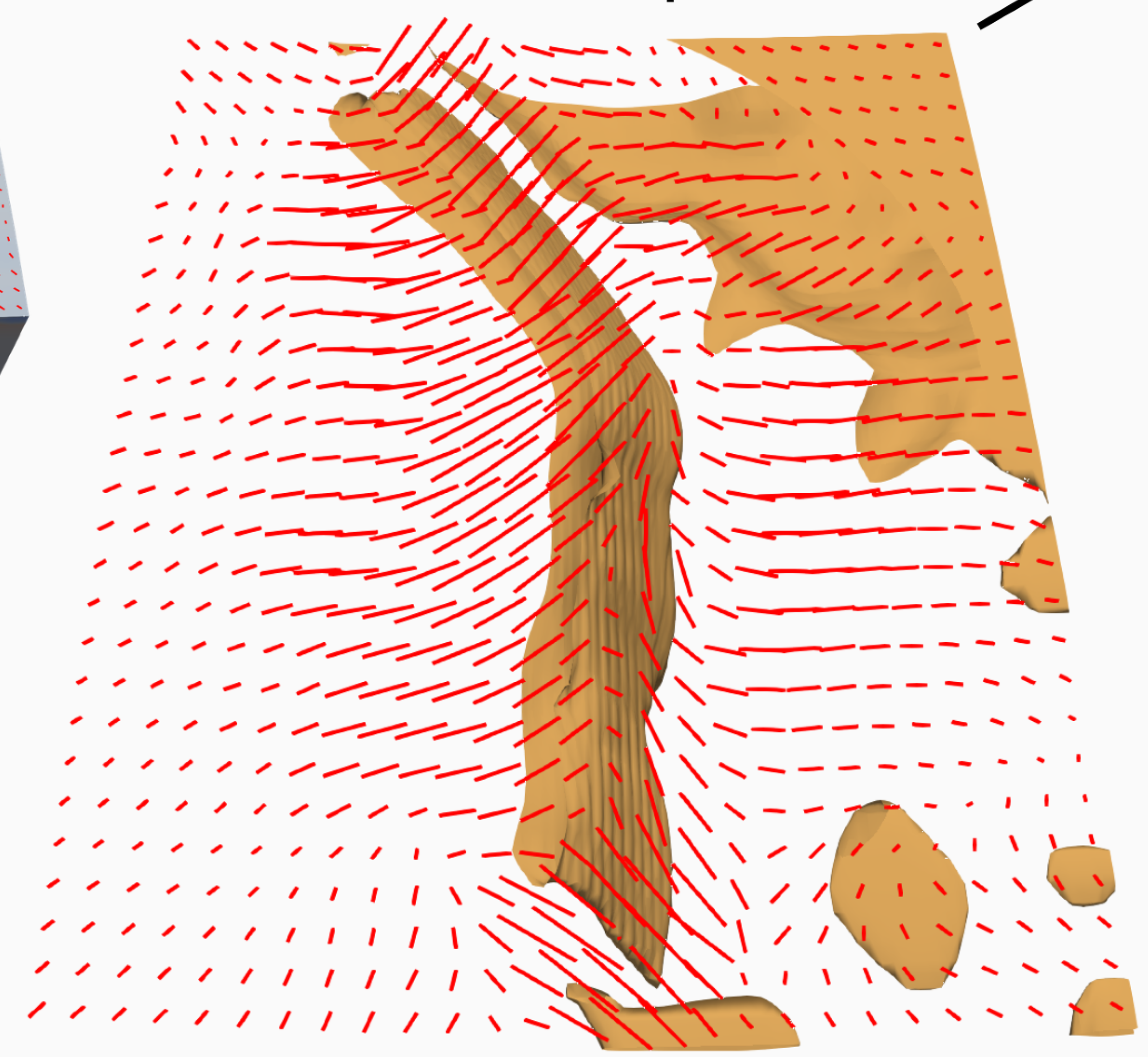


SKS-SPLIT

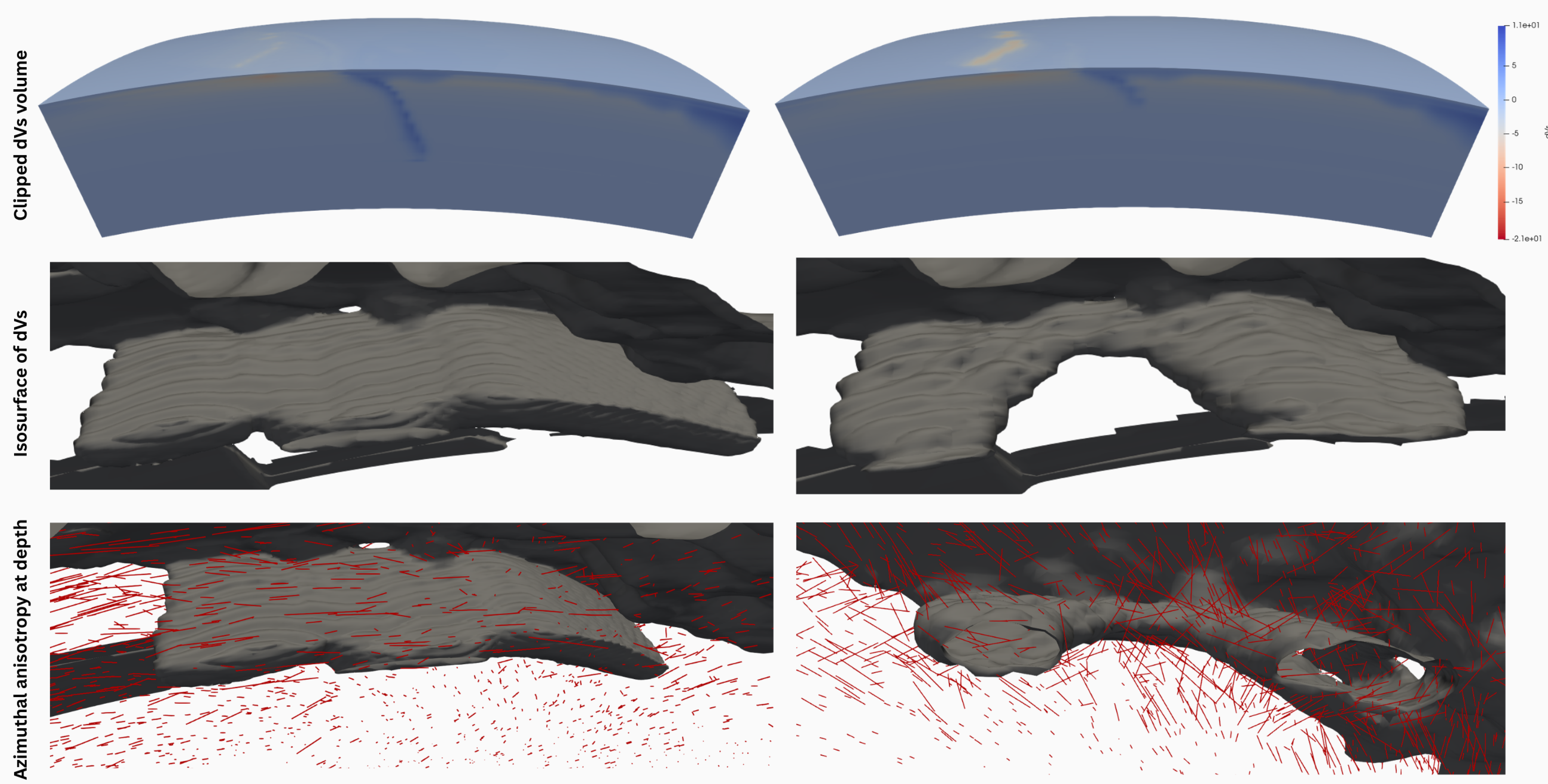
Use predicted seismic wave velocities to calculate synthetic SKS splitting times

VIZTOMO

Interpolates radial anisotropy, density (ρ), Vp, Vs, dVp, and dVs onto a tomographic grid for visualization of the elastic properties of the ***C*** tensor



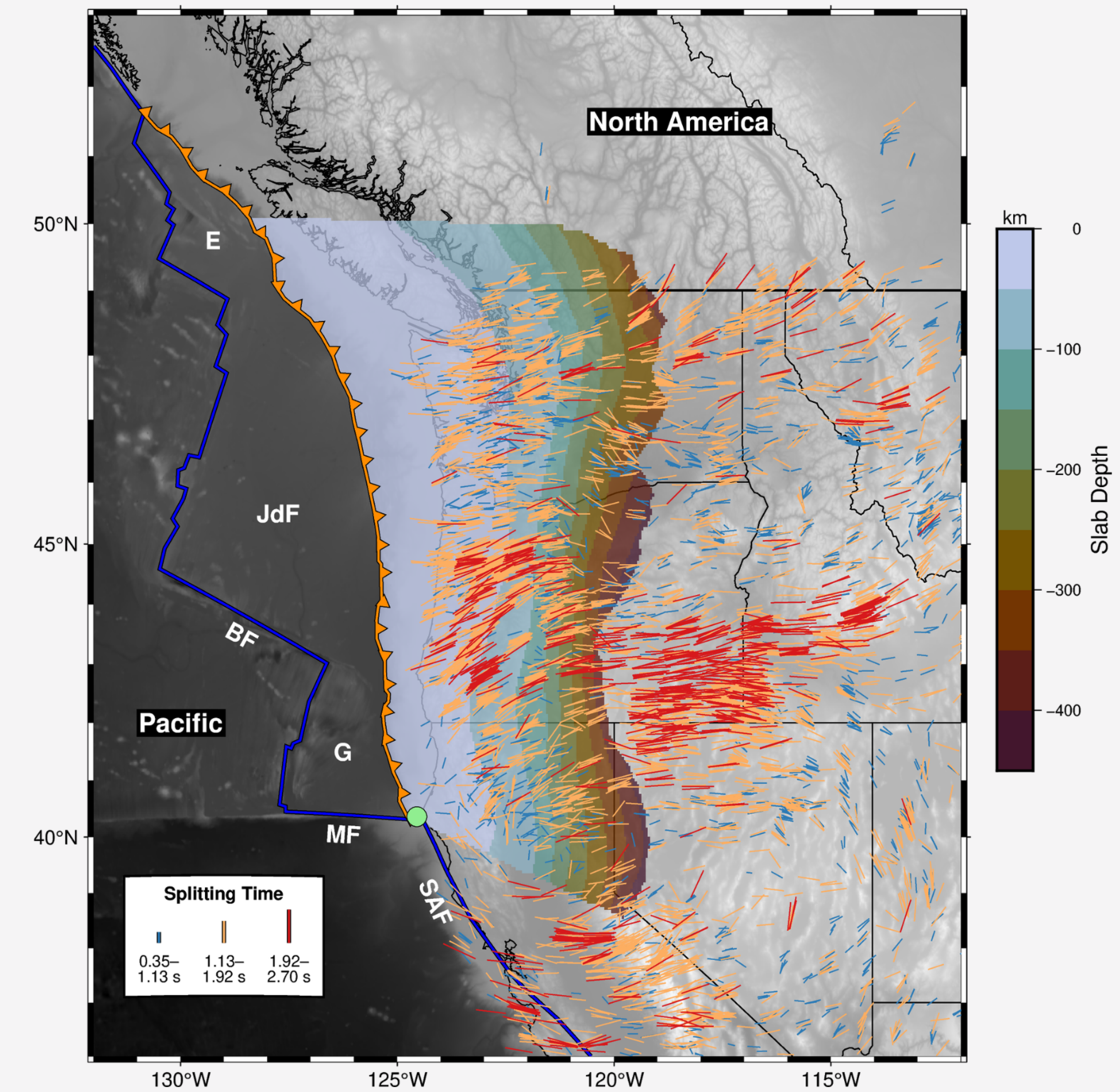
Predicted SKS splitting at the surface. Slab isovolume extracted at dVs = 2%. Model run at 15 km resolution, with LPO evolution advected over 3 Ma.



~60 km resolution, LPO evolution advected over 1 Ma

ANALYSIS

Compare to observed SKS splitting in Cascadia



SKS splitting measurements from Yang et al., 2016

Preliminary Results

- Slab geometry is distinctly visible in predicted velocity/velocity anomalies for both models from VIZTOMO, even in low resolution models
- Azimuthal anisotropy at depth follows hypothesized flow patterns
  - Trench-parallel flow around slab for gapless model (28.37)
  - 3D toroidal flow around slab edges and through the slab gap (29.37)
- Preliminary predicted SKS splitting results for model 28.35 show poor agreement with some features of observed SKS splitting in Cascadia, such as the Nevada swirl

Next Steps

References & More Info

- Run analysis at a high (10 km) resolution across all 6 models
- Compare predicted splitting to observed SKS splitting
- Compare flow patterns to velocity field at depth, particularly near predicted gap region
  - Determine where dominant components of anisotropy originate
  - Assess to what degree LPO is an accurate indicator of flow orientation