Subduction dynamics and mantle anisotropy: modeling and clustering of olivine textures

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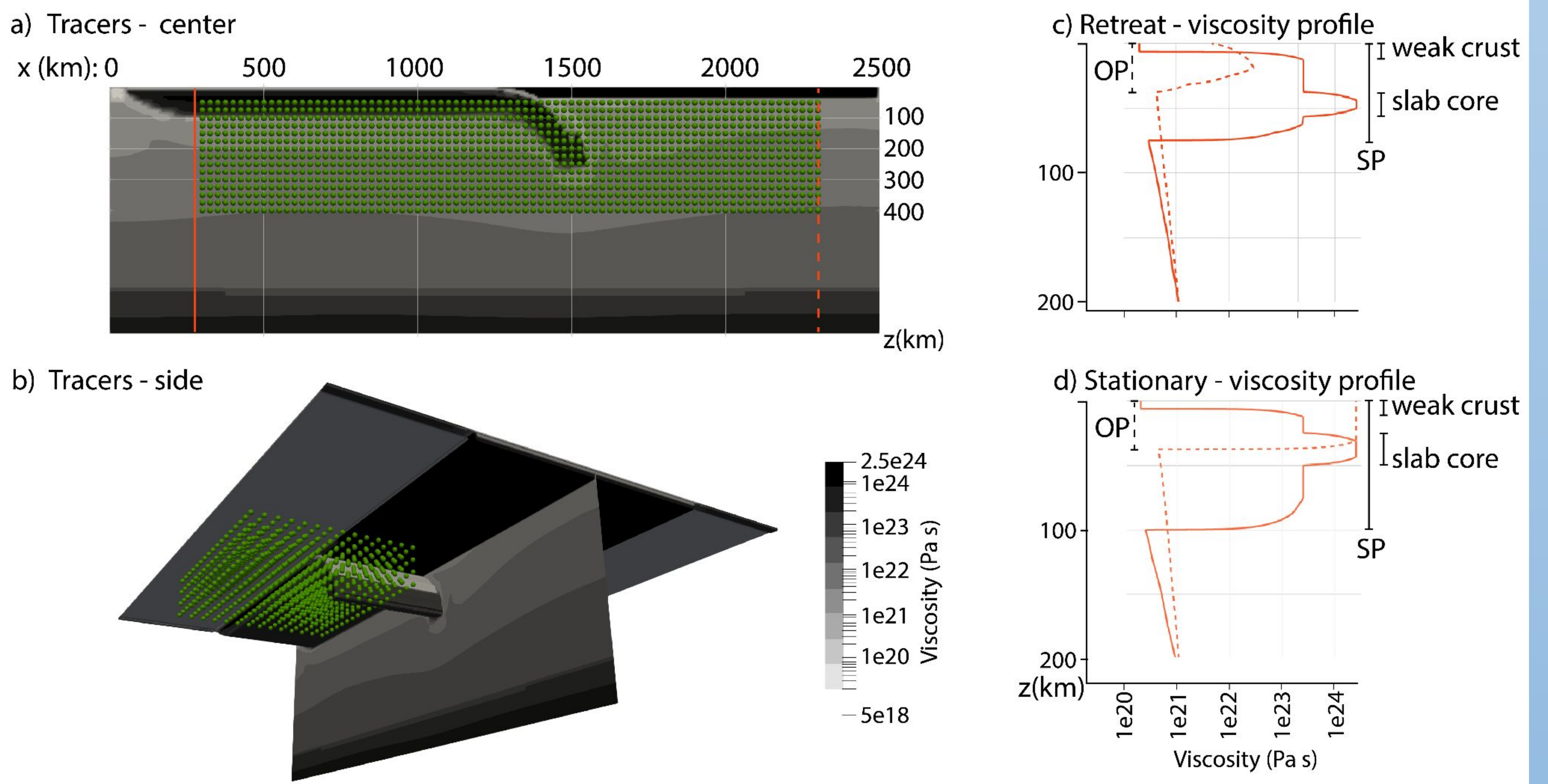
Introduction

The mantle near Earth's subduction zones experiences significant deformation, forming anisotropic rock textures. These textures can be detected using seismic methods and simulated in geodynamic models. This study employs time-series clustering to examine tracers in subduction models, identifying regions with similar deformation histories, olivine crystallographic-preferred orientation (CPO) development, and CPO-induced anisotropic viscosity. We compare the evolution of olivine textures predicted by various numerical methods for both retreating and stationary trench subduction settings.

We use three numerical methods for olivine texture development in this study: **D-Rex[3,4], the modified director method (MDM)[5], and the MDM+AV method[6]**. The MDM+AV method utilizes the best-fit Hill's parameters obtained to represent the anisotropic viscosity tensor. To investigate the mantle flow patterns in **a retreating-trench and stationary-trench subduction settings** and the effect of AV in different regions, we perform a **time-series clustering analysis** on particles placed around the slab based on features related to **particle location (coordinates), texture (pointiness, girdleness, m-index) and texture-induced AV (AV/IV ratio).**

Model settings



Time-series clustering workflow

- Construct database from model results, n **number of tracers** * p **time steps** * q **features** (LPO and AV related quantities)
- Use **Principal component analysis** (PCA) to study **feature importance**
- **Time-series k-means** clustering using **dynamic time warping** (DTW) with different k and multiple runs
- Select the "best" result with **the most similarity within cluster and most separation among clusters**

Discussion

- **Time-series clustering successfully identified groups of particles with distinct evolution history in their textures and texture related features**
- **Clustering analysis identified smaller groups with the wedge, sub-slab and plate regions**
- **With anisotropic viscosity implemented, this method could also link the effect of AV to different regions of a subduction zone with different subduction dynamics**

References

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[5] Hansen, L., Conrad, C., Boneh, Y., Skemer, P., Warren, J., & Kohlstedt, D. (2016a). Viscous anisotropy of textured olivine aggregates: 2. Micromechanical model. Journal of Geophysical Research-Solid Earth, 121(10), 7137-7160. doi:10.1002/2016JB013240Kaminski, E., Ribe, N., & Browaeys, J. (2004).
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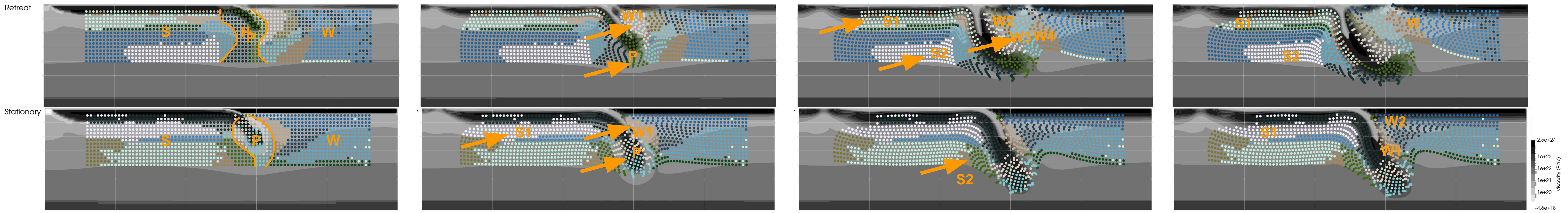
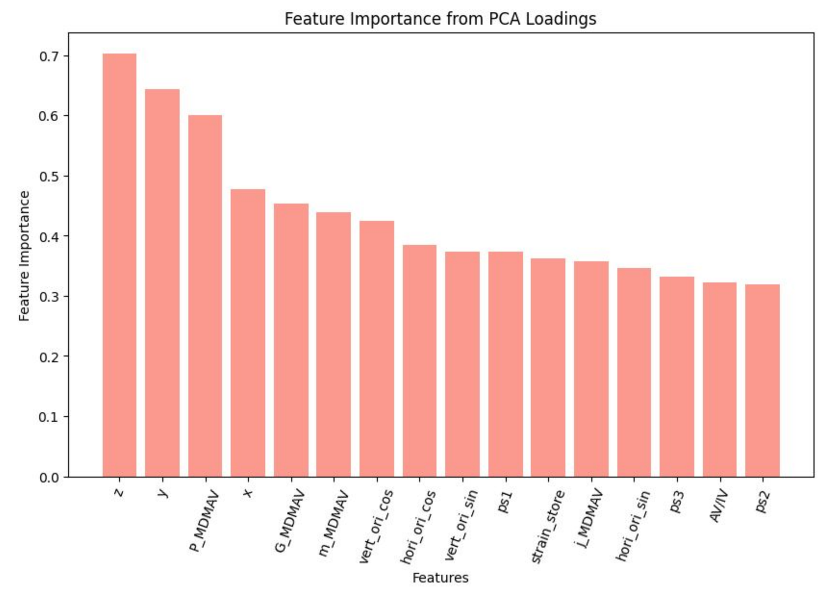
Results - Center



Key results from clustering

- The subducting plate and surrounding material (group P) which subduct into MTZ are clustered together
- Groups sub-slab (S) and mantle wedge (W) separated by group P



- Most important features includes: coordinates, the pointiness, girdleness and orientations.
- Clusters have different textures evolution through time (orientations and strength - pointiness score)

Clusters and their textures

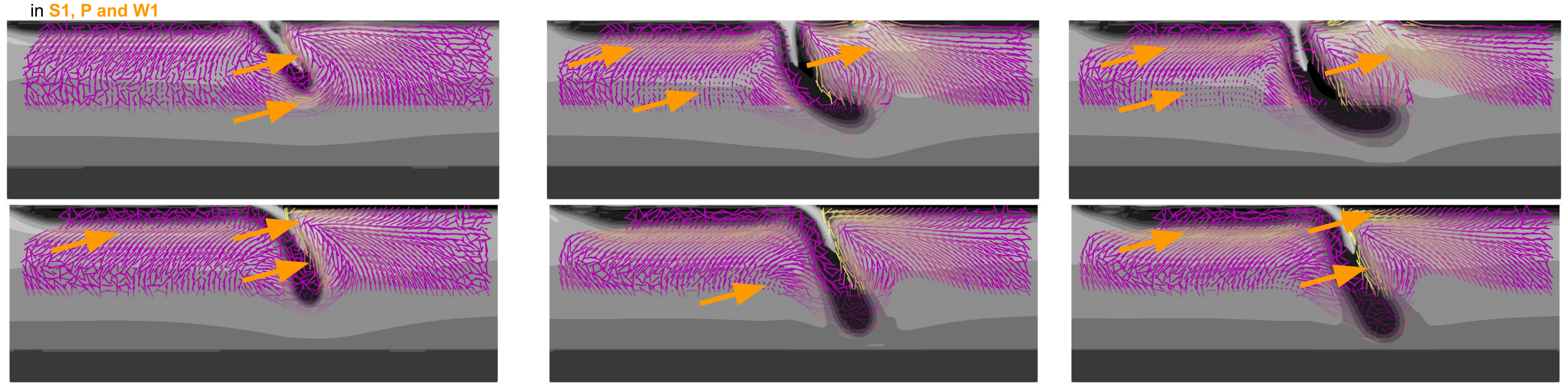
- With a retreating trench, horizontal flow following the trench motion dominates, compared to the stationary-trench model where vertical flow dragged by the slab dominates.
- Retreat: strong TN textures forms in **P**, some TN textures in **W1**
- Stationary: more slabs subducted => stronger TN textures in **S1, P and W1**

Clusters and their textures

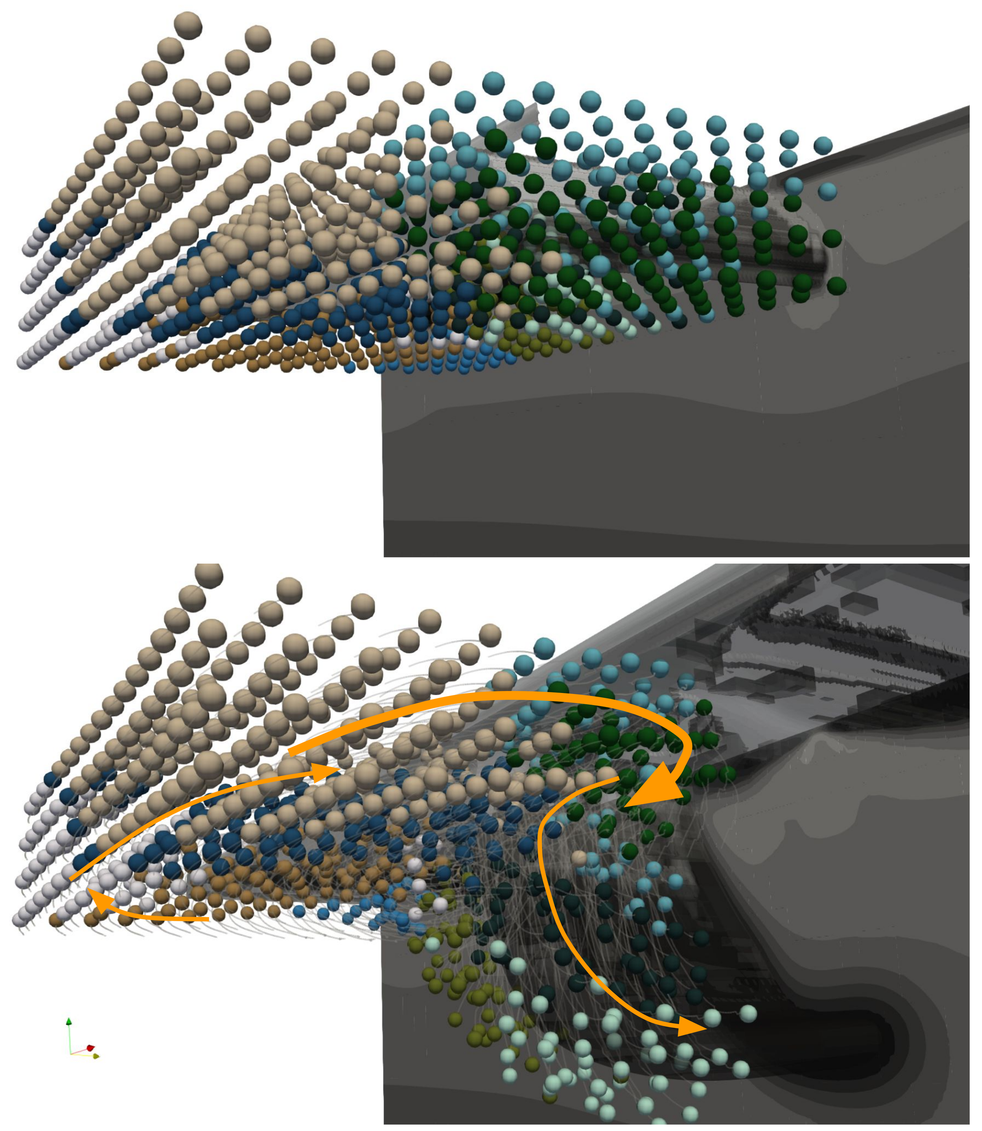
- Retreat: TN textures beneath the slab (**S1**) and TP textures behind the slab (**S2**), clusters farther in W (**W234**) are dragged towards the trench, forming TN textures
- Stationary: small bunch of TP textures (S2)

Clusters and their textures

- Retreat: TN orientations starting from 150 km away from the trench (**W**) is widespread, with some TN orientations directly beneath the slab (**S1**) and TP orientations between 300 and 400 km beneath the subducting plate (**S2**).
- Stationary: Strong TN orientations directly beneath plates (**S1 and W2**) and at the interface (**W1**)

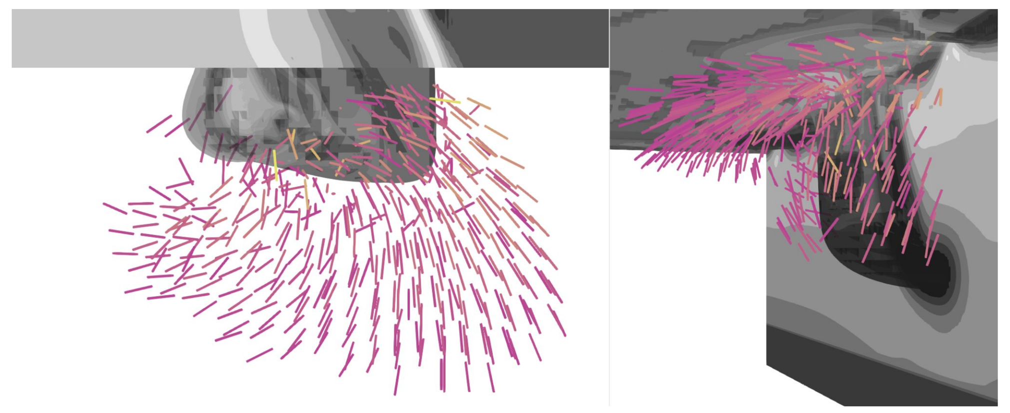


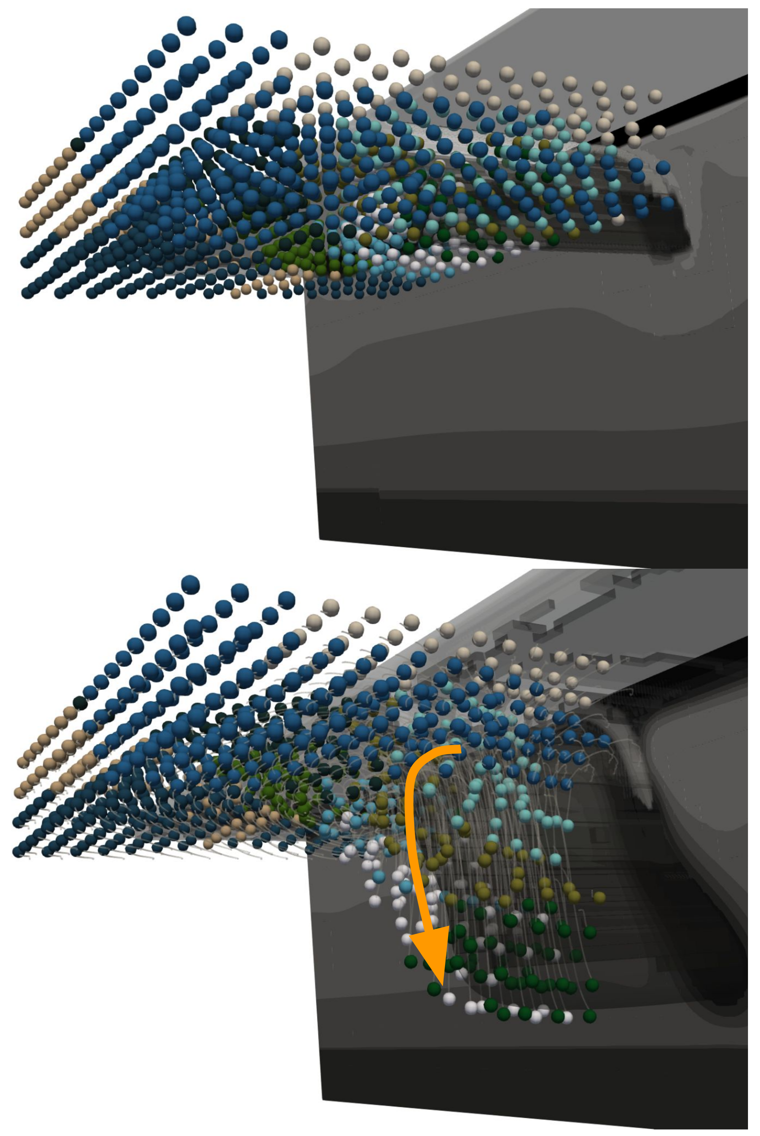
Results - Side



Clusters and their textures - Retreat

- **Toroidal** flow dominates
- Similar to the center, clustered into subducting plate and mantle around the plate
- Horizontal orientations at different angles to the trench on the side of the slab
- Stronger horizontal textures compared to the stationary-trench model





Clusters and their textures - Stationary

- **Slab-induced poloidal flow** dominates
- Strongest textures with vertical orientations only for the **P** cluster
- Weaker horizontal textures compared to the retreating-trench model