MANTLE WEDGE SEISMIC ANISOTROPY AND SHEAR WAVE SPLITTING: EFFECTS OF OBLIQUE SUBDUCTION

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Abstract

We investigate olivine crystal preferred orientation (CPO) and its effect on shear-wave splitting (SWS) in the mantle wedge of oblique subduction zones. The results show that the seismically fast axis does not necessarily align with the flow direction, particularly in the mantle outflow and transition regions, contrary to the common assumption. Unlike normal subduction models, these models indicate considerable variation in the SWS parameter distribution among the forearc, arc and back-arc regions and with subduction obliquity, with the fast direction ranging from margin-normal to margin-parallel. **This paper has been submitted to JGR Solid Earth and is currently under review.**

1. Background

Mantle wedge flow in subduction zones with subduction direction perpendicular, or "normal" to the trench is largely 2-D. Where the subduction direction is oblique to the margin, 3-D mantle flow is expected. 3-D mantle flow is modeled using PGCtherm3D code that solves the equations of conservation of mass (1), momentum (2) and energy (3). The effect of shear heating is excluded.

$$\nabla \cdot \mathbf{v} = 0 \quad (1)$$

$$\nabla \cdot \sigma' - \nabla P = 0 \quad (2)$$

$$\nabla \cdot (k\nabla T) - \rho c_P (\mathbf{v} \cdot \nabla T) + Q_H = 0 \quad (3)$$

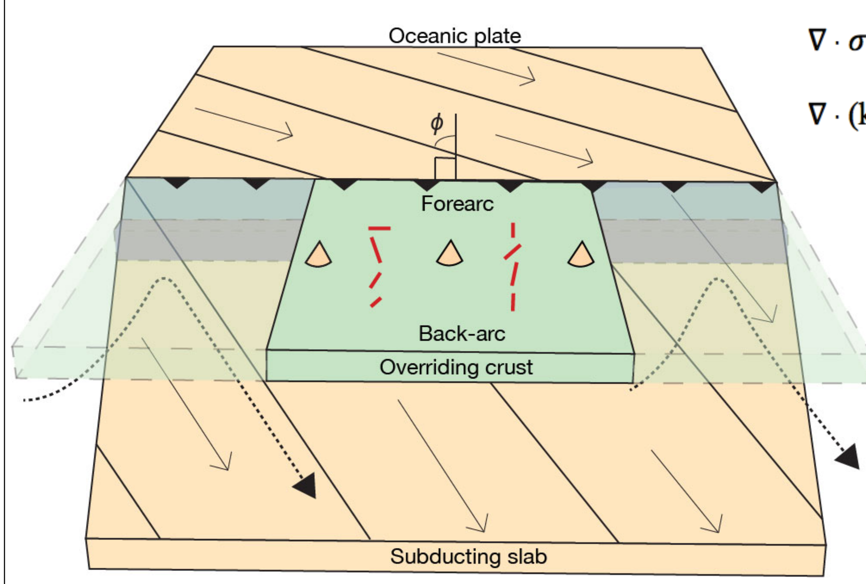


Figure 1.1. Oblique subduction, conceptual figure with red bars indicating possible SWS fast directions

We use D-Rex to calculate the fast directions in 3-D, assume an A-type olivine fabric, a 70% olivine 30% enstatite aggregate and parameters of λ = 5, χ = 0.3 and M*=125. The shear wave splitting parameters are calculated using anisotropic elasticity tensors generated by D-Rex and a SWS code utilizing the MSAT toolbox. We assume vertical ray paths and a frequency of 0.5 Hz to mimic local S-wave frequency content.

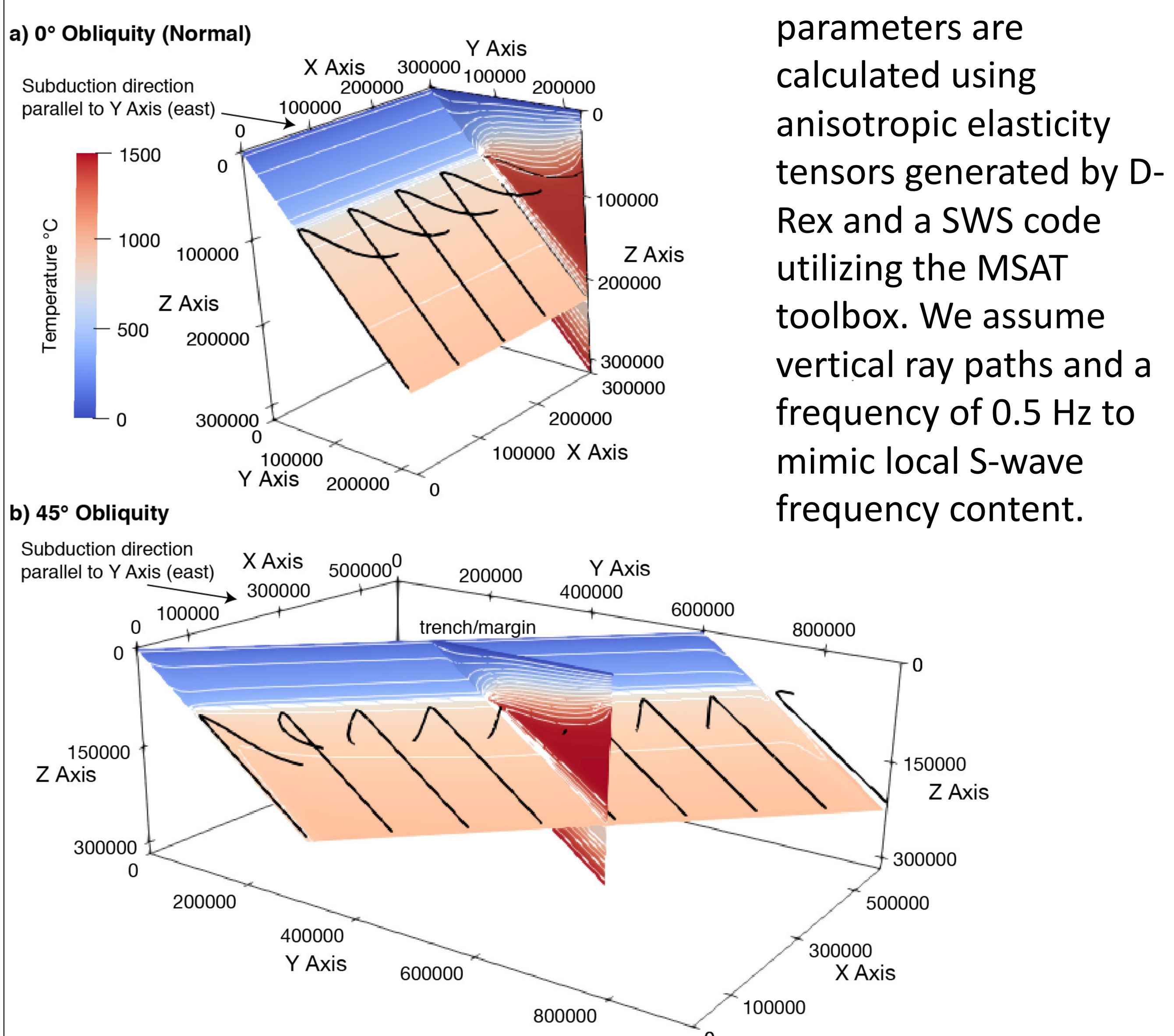


Figure 1.2. 3-D oblique subduction model with black flow path lines and cross section orientation

2. Results

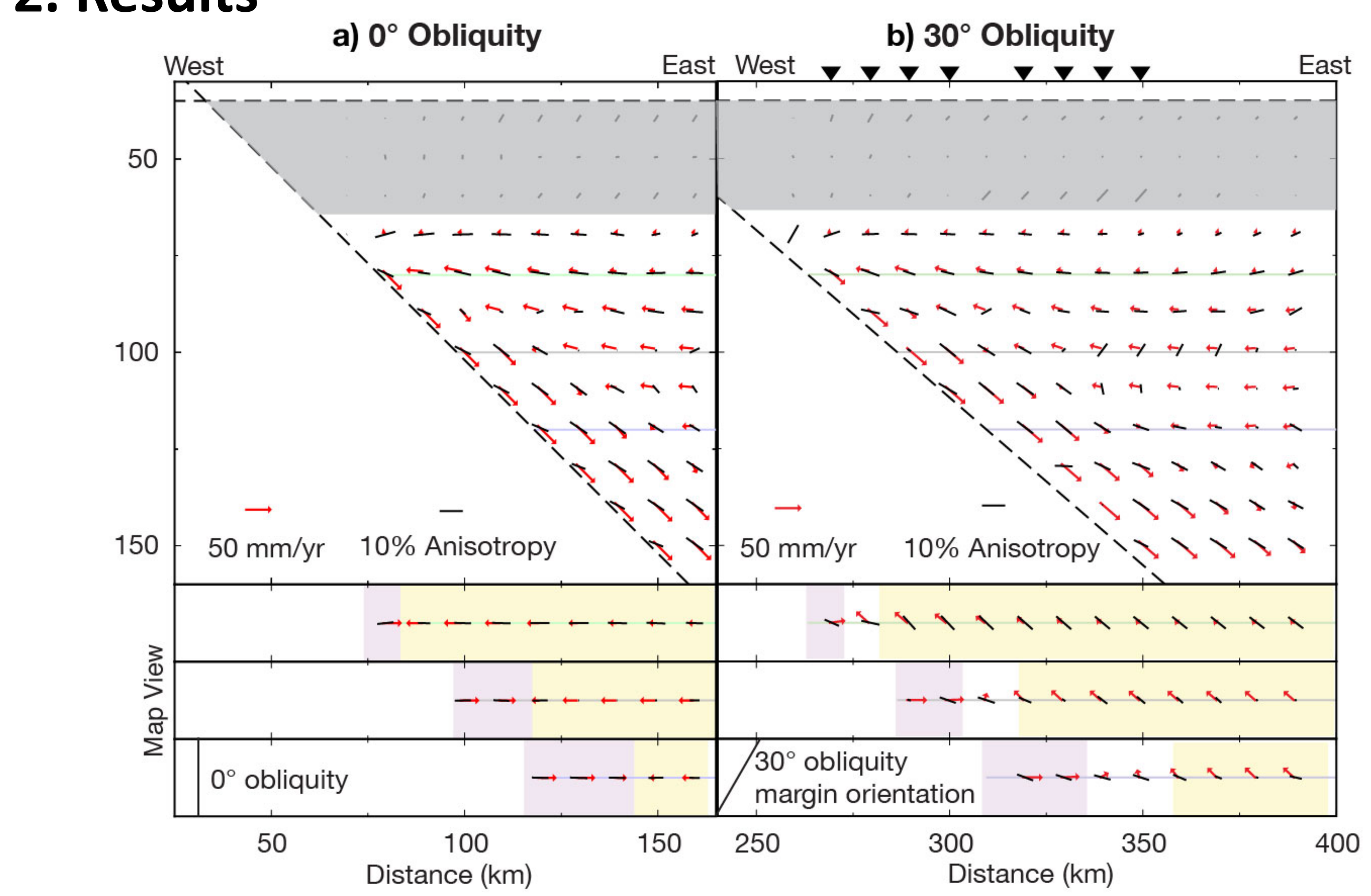
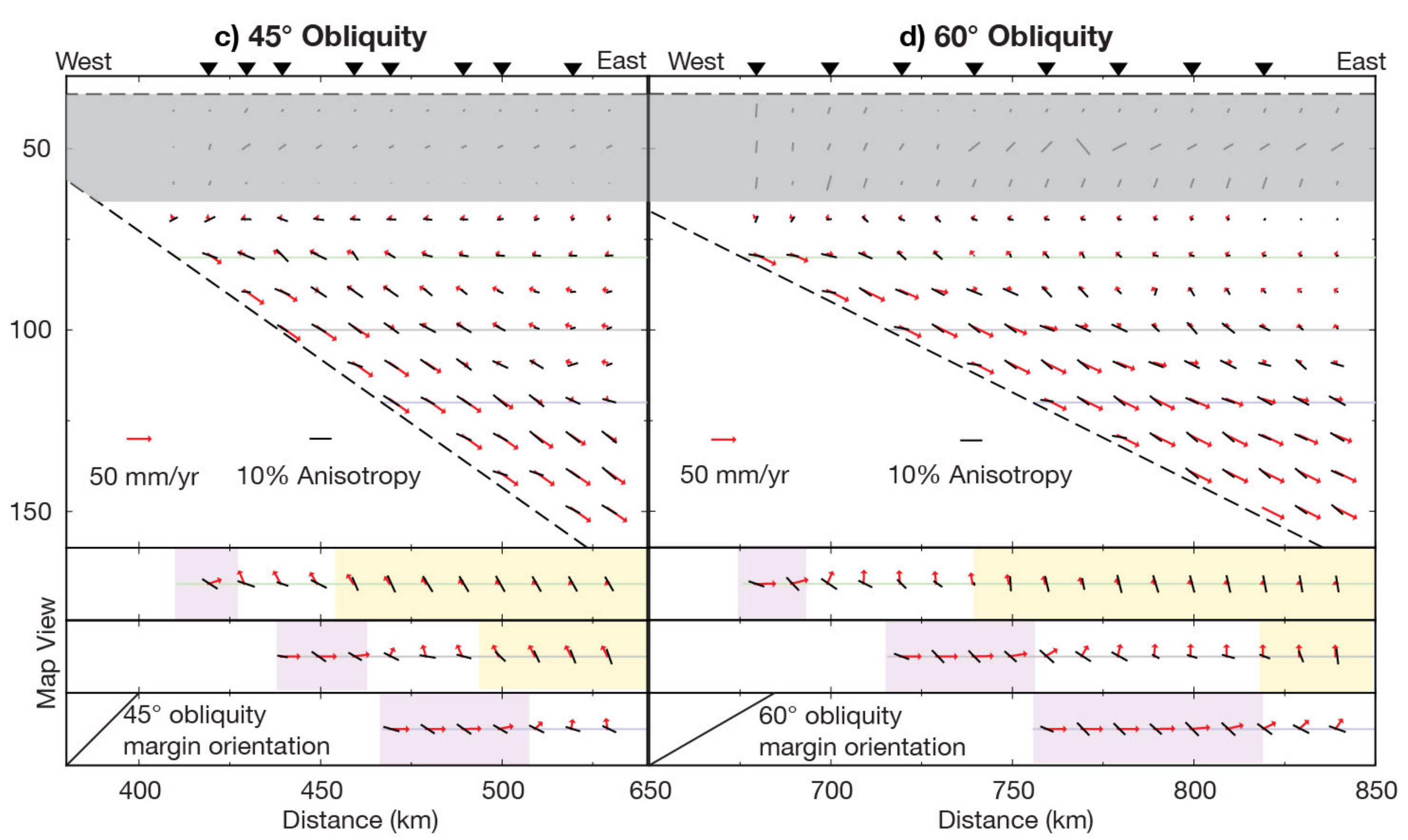


Figure 2.1. Mantle flow vectors and average olivine a-axis orientations. The figure shows red flow velocity vectors and black fast direction bars for A-type olivine. The top panel with cross sections taken parallel to the subduction direction and are not perpendicular to the trench (as in **Figure 1.2**). The 3-D vectors are being projected onto a plane that is oriented E-W resulting in only E-W and vertical component of the vector being plotted here.



The flow vectors and the average a-axis are aligned at the shallow part of the mantle wedge where material is flowing in from the back-arc toward the mantle wedge corner.

In the transition from inflow to outflow, the flow vector and fast direction no longer align.

Once entrained by the slab in the outflow, the flow direction and fast direction remain offset with a larger offset observed for larger subduction obliquity.

In the forearc region, the SWS parameter distribution is "bimodal" in that there are two fast directions with a primary and secondary peak delay times that are generally margin perpendicular and margin normal, respectively. However, the majority of the fast directions are margin normal

In the arc region, the SWS parameter distribution is also bimodal, although peak delay times are larger, secondary peak delay times are shorter and non-peak delay times are larger than in the forearc. Most of the fast directions are margin normal.

In the back-arc, the SWS parameter distribution is more obliquity dependent, with the range of fast directions being much smaller for the 30° obliquity model. Fast directions range from margin normal or margin oblique.

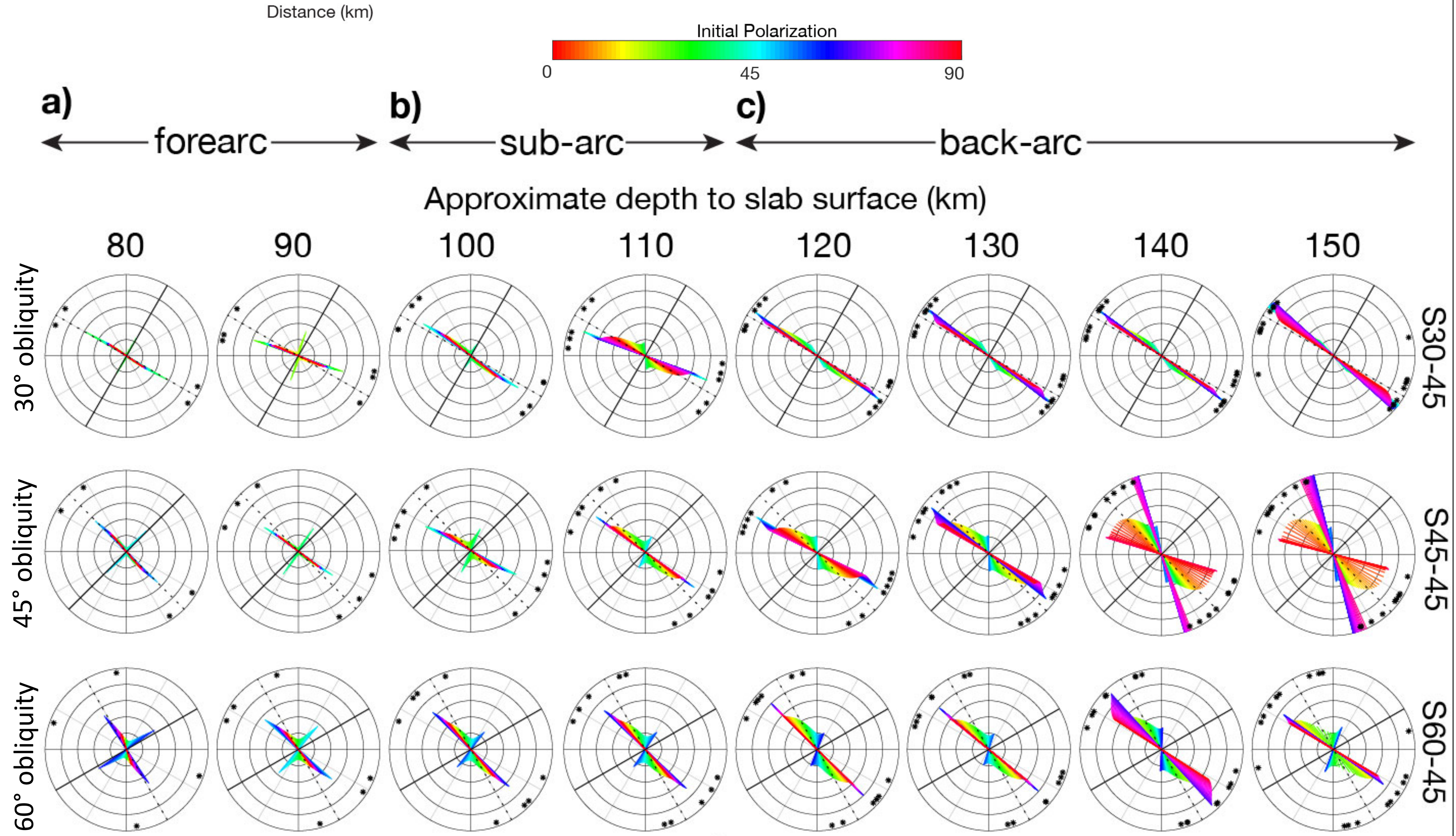


Figure 2.2. The SWS polar plots to the right are plotting the azimuth of the fast direction and a radial length based on delay time. All color bars indicate the direction of the initial polarization of the S-wave. The solid line indicates the margin-parallel direction and the dashed line indicates the direction perpendicular to the margin. The *s indicate individual layer fast directions. The results here are plotted in order of increasing obliquity, and from forearc to back arc. The locations of these SWS parameters are indicated by inverted black triangles in **Figure 2.1**.

3. Conclusions

For larger obliquities we see larger offsets between the mantle flow direction and the average a-axis orientation in the outflow region

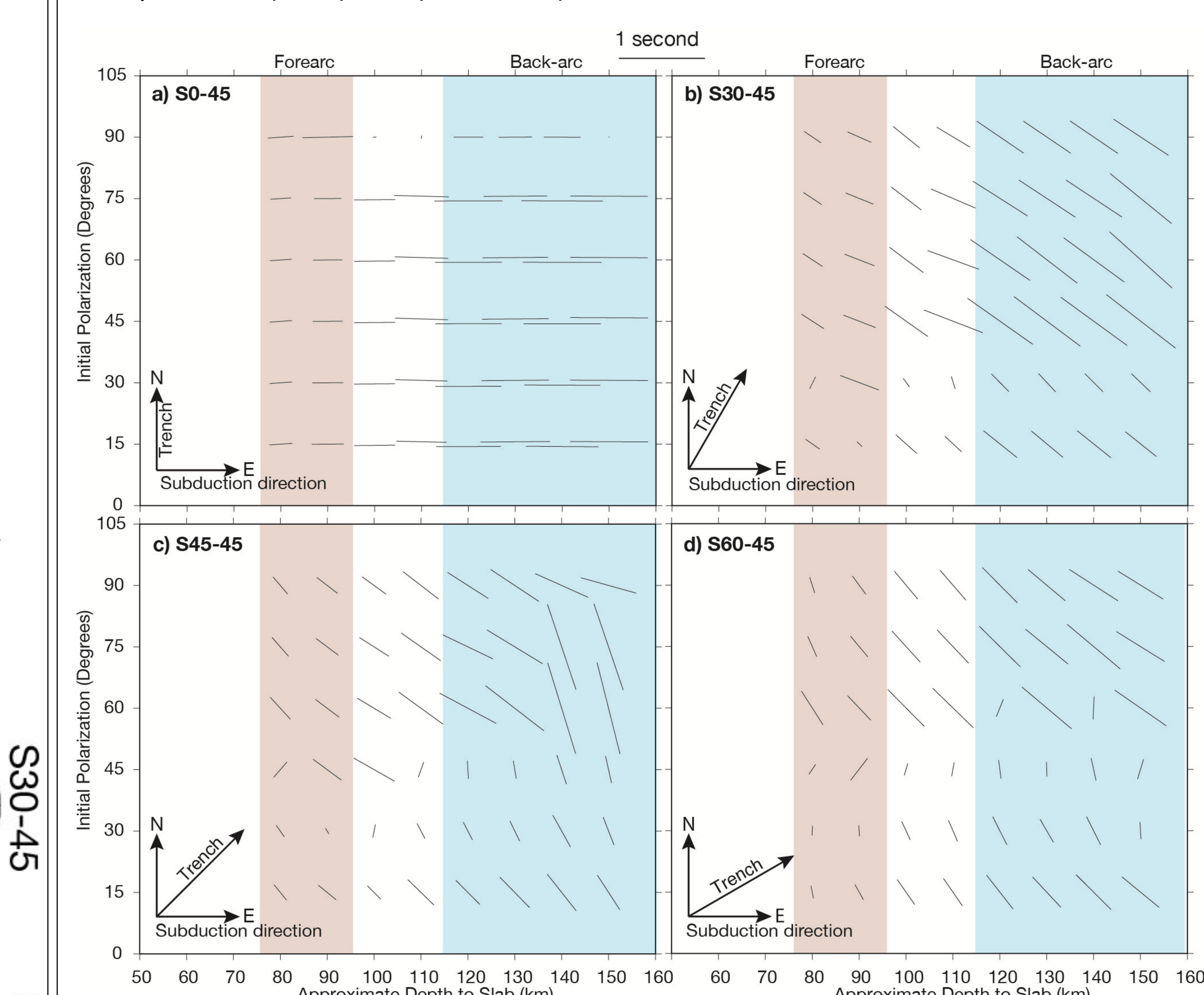
The SWS in the forearc is mostly margin normal, but for models with obliquity margin parallel fast directions are possible, although they have smaller delay times.

The SWS in the arc region are similar to the forearc, but with increasing delay times for margin normal fast directions.

The back-arc region SWS has only margin-normal and margin-oblique fast directions. The fast directions for 30° obliquity have variable delay times, but a small range of margin-normal fast directions. The 45° and 60° obliquity models have more widely varying fast directions and delay times.

Our SWS results indicate that we cannot explain the common observation of margin parallel fast directions in the forearc of subduction zones. We do expect that subduction obliquity would likely result in a a wider variation of fast directions and delay times assuming an even and wide distribution of initial polarizations.

Figure 3.1. SWS results by depth to slab and initial polarization for subduction obliquities of a) 0° b) 45° c) 30° and d) 60°



Acknowledgements

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Figures are generated using the Generic Mapping Tool software and MATLAB.