SEISMIC ANISOTROPY AND IT'S GEODYNAMICAL IMPLICATIONS IN SRI LANKA REGION USING SHEAR-WAVE SPLITTING ANALYSIS

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ABSTRACT

Anisotropy, a term used by the seismologists to describe the variation of seismic wave velocity in different directions, is an excellent tool to examine the deformation (past and present) in the upper mantle. Seismic anisotropy beneath Sri Lanka region is investigated using core-refracted SK(K)S phases at 3 stations, namely MALK, PALK and HALK. The shear wave splitting measurement results in Sri Lanka shows the presence of two anisotropic layers in the upper mantle, viz., NW-SE fast polarization direction for MALK and HALK, and NE-SW for the PALK stations in the upper layer; NNE-SSW for MALK and HALK, and NW-SE for PALK in the lower layer Overall, fast polarization direction for Sri Lanka region is found to be NE-SW. The delay time in the upper and lower layer is found to be between 0.3-0.5 s and 0.6-0.9 s, respectively. Comparison of Absolute Plate Motion (APM) direction with fast polarization directions infer that the Simple Asthenospheric Flow (SAF) model prevails in this region. On the other hand, Comparison of Maximum Horizontal stress (S_{hmax}) and the Global Positioning System (GPS) with the fast polarization direction infer that there is partial contribution from lithospheric mantle. So, the anisotropy in Sri Lanka is mainly governed by asthenospheric flow, and partially due to lithospheric mantle.

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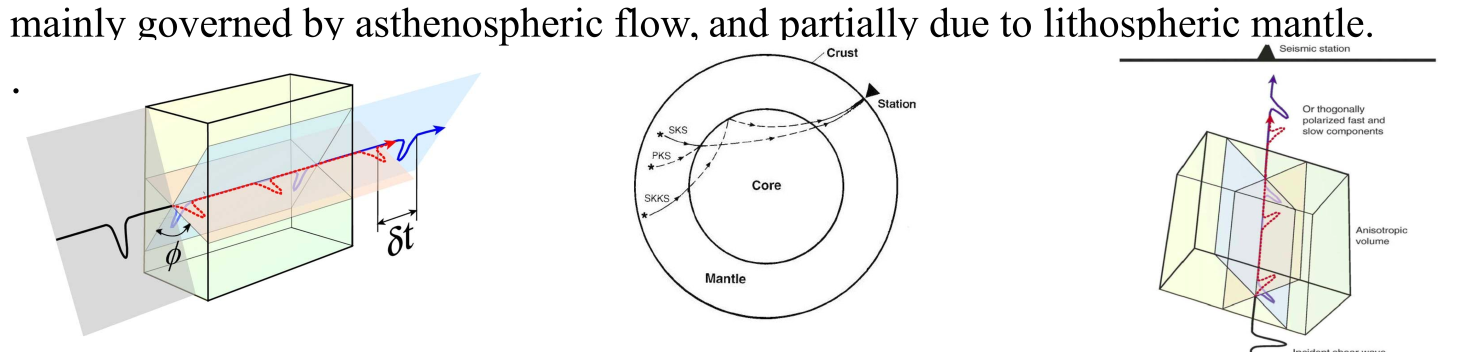


Fig. 1: Cartoon representation of Shear-wave splitting phenomenon and XKS (SK(K)S, PKS) phases used to measure upper mantle anisotropy.

GEOLOGIC SETTING OF STUDY AREA

- Sri Lanka is tectonically complex and geologically very diverse compared to the other old continental terrains.
- It comprises of four different lithological units, which were distinguished on the basis of isotopical, geochronological, geochemical and petrological constraint, viz., the Highland Complex (2-3 Ga), the Wanni Complex (1-2 Ga), the Vijayan complex (1-1.9 Ga) and the Kadugannawa Complex (1-2 Ga).

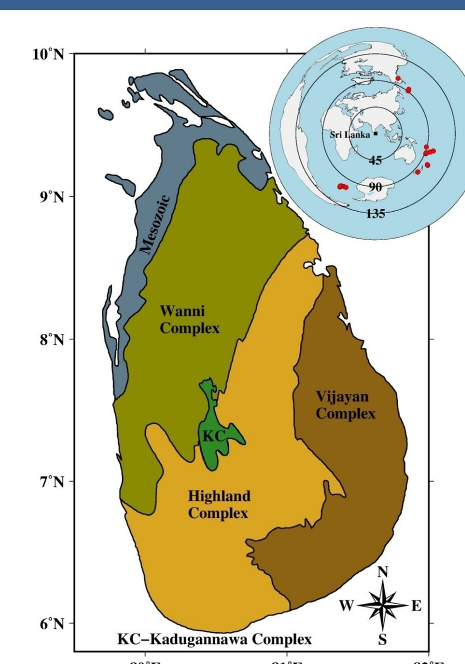


Fig. 2: Geological map of Sri Lanka with all the lithological units. All the events that provide best splitting results are shown at the top most corner of the plot.

METHODOLOGY

- Two complementary types of techniques are used to find the fast axis orientation (Φ) and delay time (δt):

1. Rotation-correlation method (Bowman and Ando, 1987) Search for maximum cross correlation coefficient between the waveforms on the radial and transverse components in the selected window.
2. Minimum energy method (Silver and Chan, 1991) Search for the minimum energy of the displacement on the transverse components.

- Thicknesses of anisotropic layer beneath each station are estimated by assuming a shear velocity (Vs) of ~4.6 km/s and a 4% anisotropy for the upper mantle (Booth and Crampin, 1985), using the following formula: $\mathbf{L = (\delta t V s)/A}$ (i)

where L and δt are the thickness of lithosphere (km) and mean delay time(s) respectively. A is the percentage of seismic anisotropy.

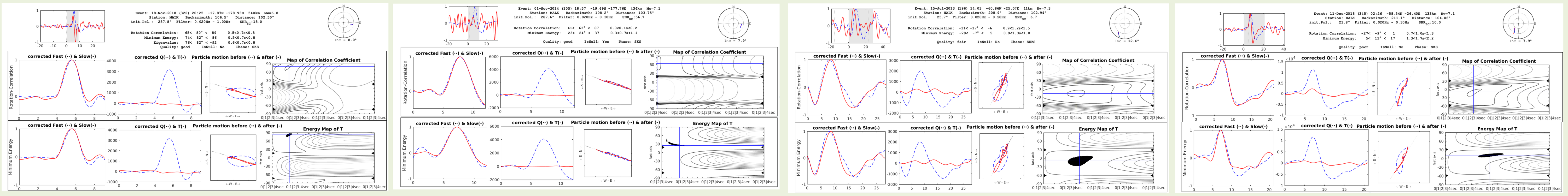
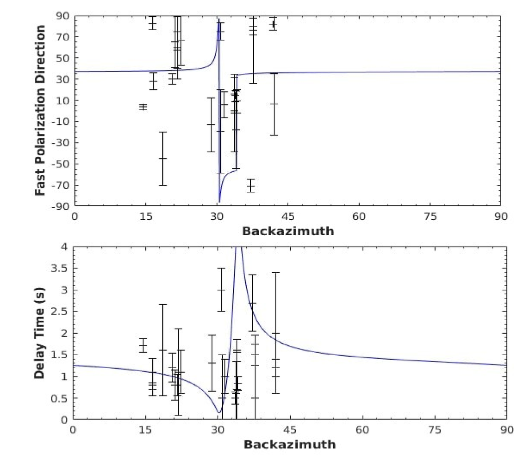


Fig. 3: Examples of shear wave splitting measurements on an SKS phase using the SC and RC methods carried out using the SplitLab package (Wustefeld et al. 2007).

Two Layer model

- The large variation in splitting parameters, These variations between the fast and slow SK(K)S-wave arrivals are characteristic of dipping or multiple layers of anisotropy.
- We use Silver and Savage (1994) method.
- In the case of multi-layer anisotropy, variations in both ϕ and δt with backazimuth show π/2 periodicity.



DEPTH OF ANISOTROPIC LAYER

- The average crustal thickness in Sri Lanka lies between 30-40 km with moho depth greatest beneath HC (Dreiling et al. 2019). This suggest that the anisotropy measured essentially comes from the upper mantle.

Table 1. Results of two layer model and corresponding anisotropic thickness.

Station	Layer	Fast Direction	Delay time	Anisotropy Depth
MALK	UL LL	-75 24	0.3 0.6	**112.7**
PALK	UL LL	57 -63	0.5 0.9	**117.26**
HALK	UL LL	-75 24	0.4 0.7	**132**

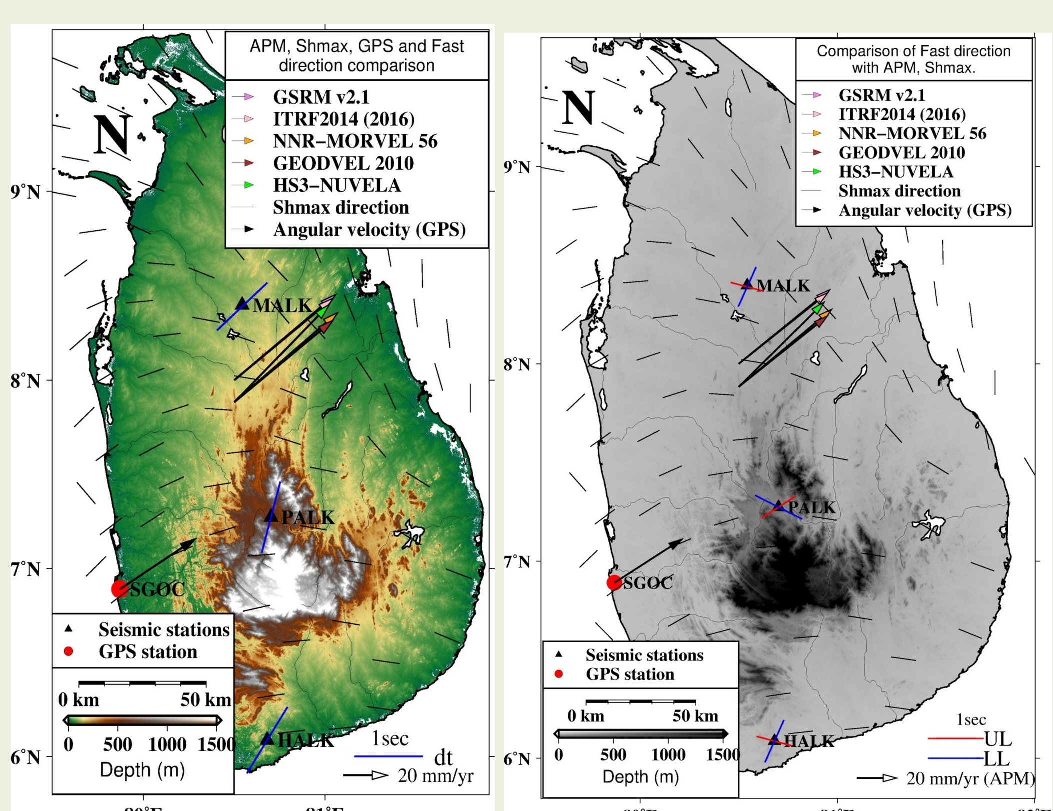


Fig. 5: (a) Average fast polarization (Φ) and delay time (δt) using SWS analysis based on single layer model **(b)** Comparison of fast polarization directions with S_{hmax} and GPS direction.

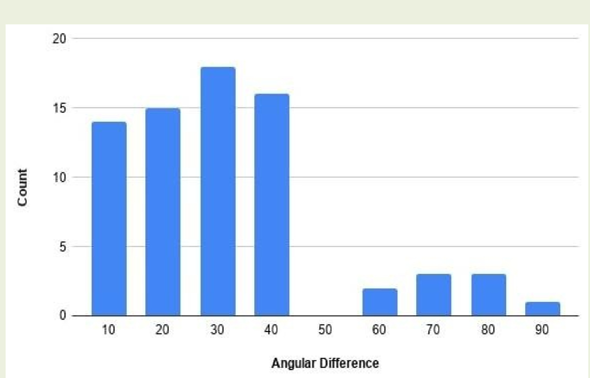


Fig. 6: Comparison of average fast Polarization (Φ) with the APM direction (Gripp & Gordon 2002).

RESULTS AND DISCUSSION

- The results show that the fast polarization direction for the lower layer can be explained by lattice-preferred orientation of olivine crystals in the asthenosphere, associated with present-day absolute plate motion of the Eurasian plate.
- The fast polarization directions are nearly consistent with the APM directions (Fig. 6). This indicates that the seismic anisotropy beneath Sri Lanka region is mainly caused by the asthenosphere mantle.
- We also compare our fast polarisation directions with the S_{hmax} directions (Yadav et al., 2018).
- Evident from **Fig. 5 (b)**, the fast polarization directions of upper layer are nearly parallel to S_{hmax} orientations, implying stress induced anisotropy in the upper layer.
- We conclude that weaker anisotropy in the upper layer is related to the anisotropy frozen in the lithosphere and relatively stronger anisotropy in the lower layer is related to the asthenospheric flow.

Conclusions

- Our findings show that, a unique double-layer model determined for the Sri Lanka region explains better the characteristics of the anisotropic parameters compared to the single-layer model.
- **Weaker anisotropy** (δt~0.2 s) in **the upper layer** is caused by the deformations in the lithosphere, while relatively **strong anisotropy** (δt~1.2 s) in the lower layer is caused by the **asthenospheric flow.**

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