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TwistPy

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Enhancement of Seismic Phase Identification using Polarization Filtering and Array Analysis

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TwistPy   Abstract

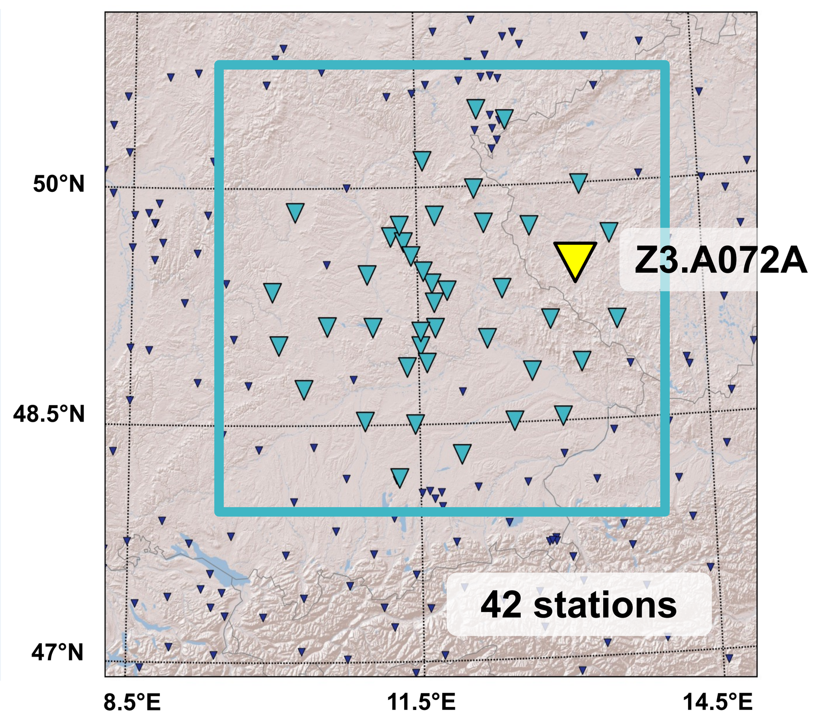
Objective

Examine whether the combination of polarization filtering in time-frequency domain with conventional array analysis can further increase the signal-to-noise ratio of coherent signals in a seismic wavefield, **allowing more robust phase identification and extraction**.

Methods

- Polarization analysis and filtering in the time-frequency domain using S-transform powered by **TwistPy** (*Sollberger, D et al., 2023*).
- Filter is designed based on polarization attributes: **ellipticity** (**ε**), **inclination** (**θ**) and **azimuth** of the major semi-axis (**φ**), and the degree of polarization (***DOP***).
- **Elevation corrections** are applied for beamforming.

Gräfenberg Array & AlpArray



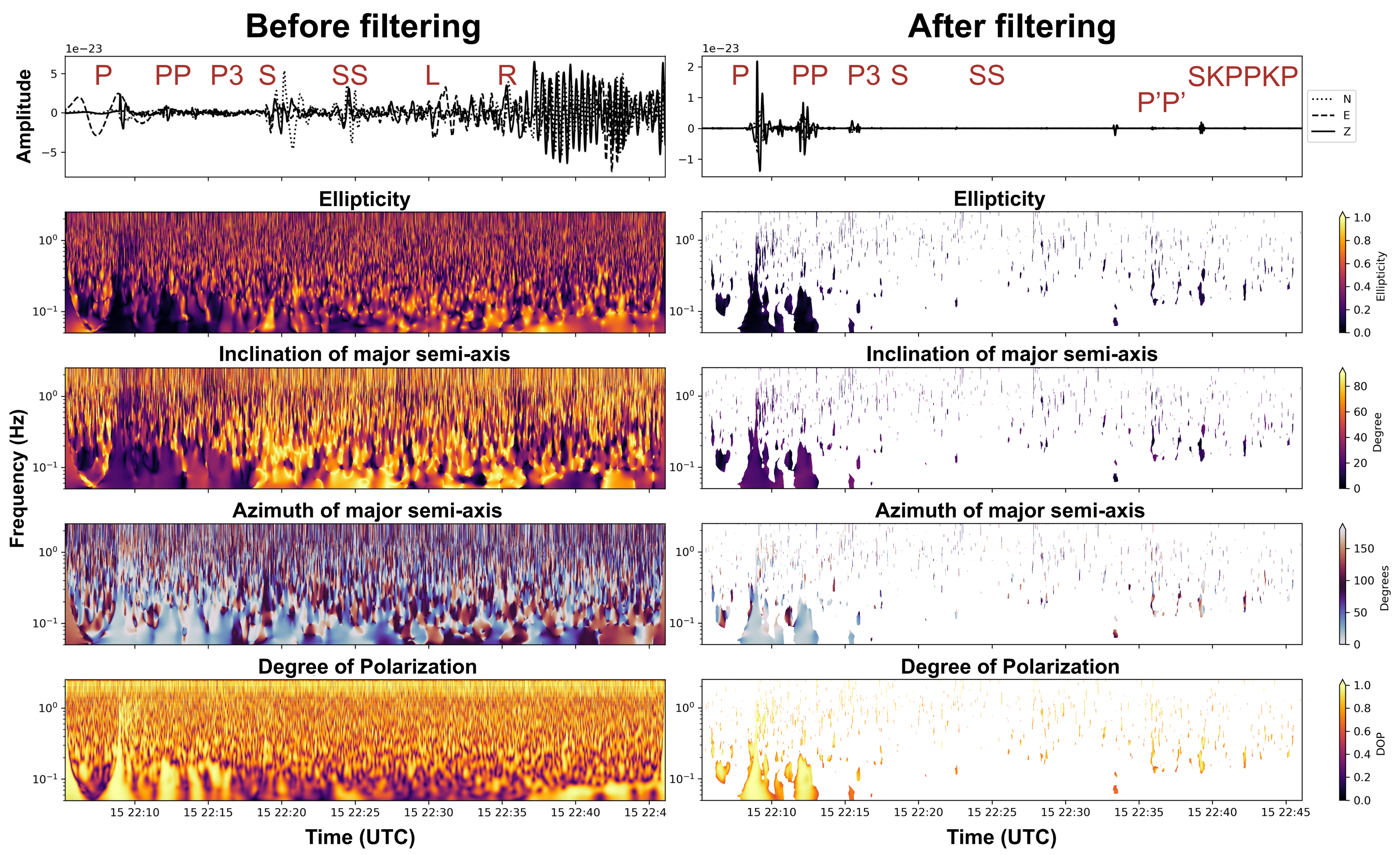


Figure: 3-component polarization analysis and filtering in the time-frequency domain of AlpArray station A720A (yellow triangle) of an example earthquake in Alaska in 2018. The waveform and spectrograms on the right are filtered mainly for linearly polarized waves arriving with high inclination and *DOP*.

Example Event

2018/08/15 Alaska M_W6.5
Depth 33.9km, Distance 79.2°, BAZ 6.2°

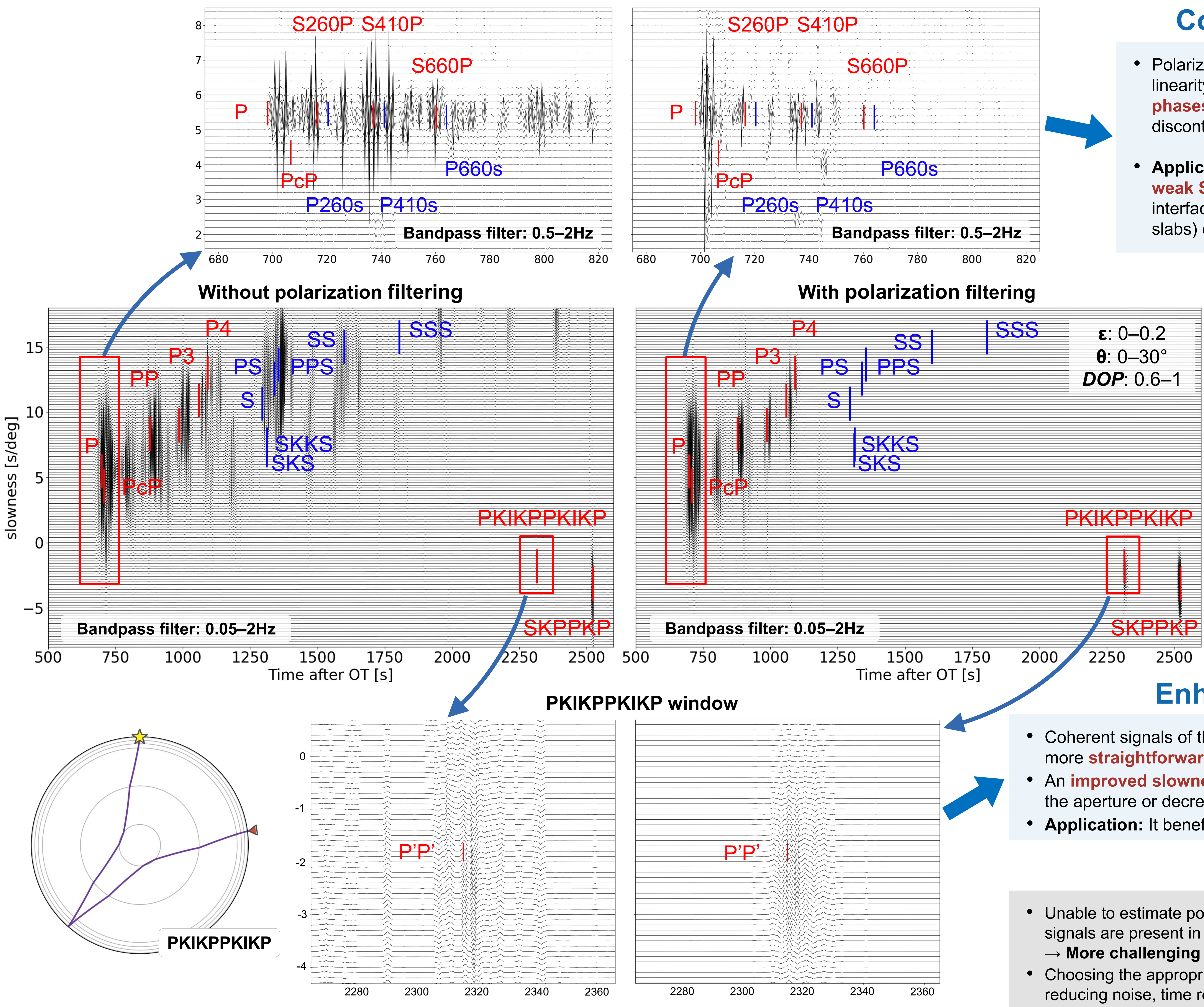


Figure: The comparison of 4[th] root vespagrams with (right panel) and without (left panel) polarization filtering for waves arriving at high inclination and linearity. The theoretical travel time and slowness of P and S phases are marked in red and blue based on earth model ak135, respectively.

Discussion

Coherent Noise Suppression

- Polarization filters for waves with high inclination and linearity help **recover some of the weak converted phases** (source-side conversions) at the upper mantle discontinuities buried in the long P-wave coda.
- **Application:** It allows the **observation and study of weak SV-signals resulted from conversion** at interfaces with significant impedance contrasts (e.g. slabs) on the vertical component.

Wavefield Separation

- Using customized polarization filters can **isolate more specific wave types** and study them individually.
- **Application:** These wavefield-separated vespagrams are significantly easier to identify different type of phases and can be **used for pick refinements** and **identification of weak phases** that are usually hard to find in single seismograms.

Enhancement of Weak Phases

- Coherent signals of the main arrival are enhanced which leads to a more **straightforward extraction of weak phases**.
- An **improved slowness resolution** is achieved without increasing the aperture or decreasing the inter-station spacing of the array.
- **Application:** It benefits the remote areas without large/dense arrays

Limitations ⚠

- Unable to estimate polarization properties accurately when overlapping signals are present in the same analysis window.
  → **More challenging for analyzing local/regional events**
- Choosing the appropriate polarization filter involves a **trade-off** of reducing noise, time resolution, or preserving the desired signals.
- Accuracy of polarization analysis is **highly dependent on the quality of data** and **choice of analysis window length**.