Towards field data applications of six-component polarization analysis

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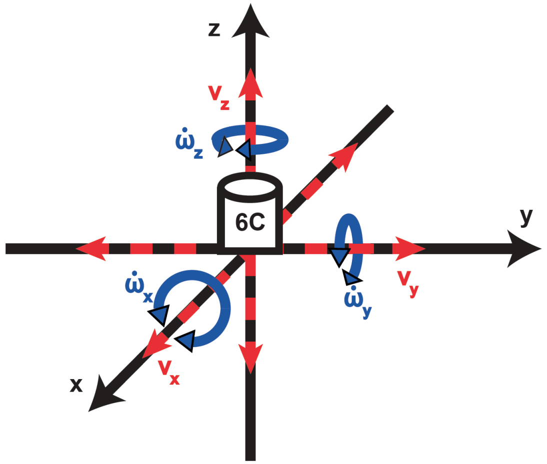
What is 6-C polarization analysis?

- Analysis of the relative amplitudes of seismic waves recorded on a single six-component (6-C) station measuring both translational and rotational ground-motion (Sollberger et al., 2018)

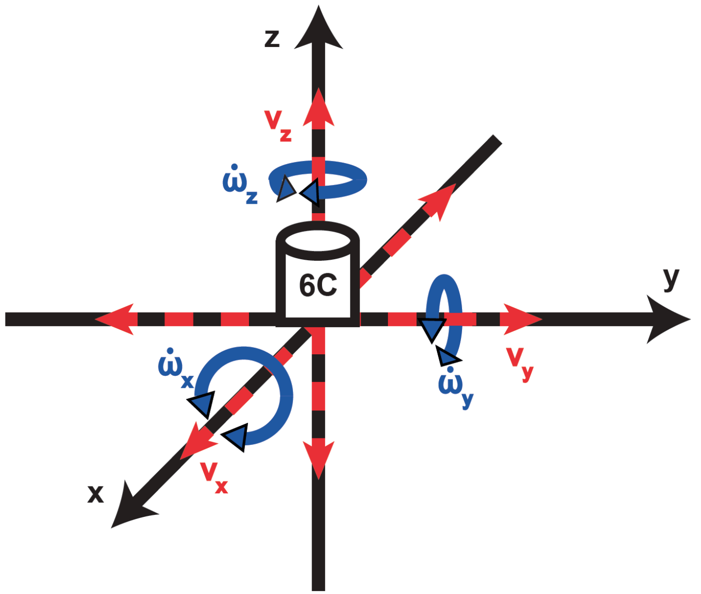
- 6-C polarization analysis with a single station allows to:
  - Automatically distinguish between different wave types (P, SV, SH, Love, Rayleigh) because their polarization patterns are unique at the free-surface (except SH and Love waves)
  - Extract phase velocities and propagation direction
  - Extract the true incidence angle at the free-surface
  - Separate seismic phases that overlap in time



Limitations of 6-C polarization analysis

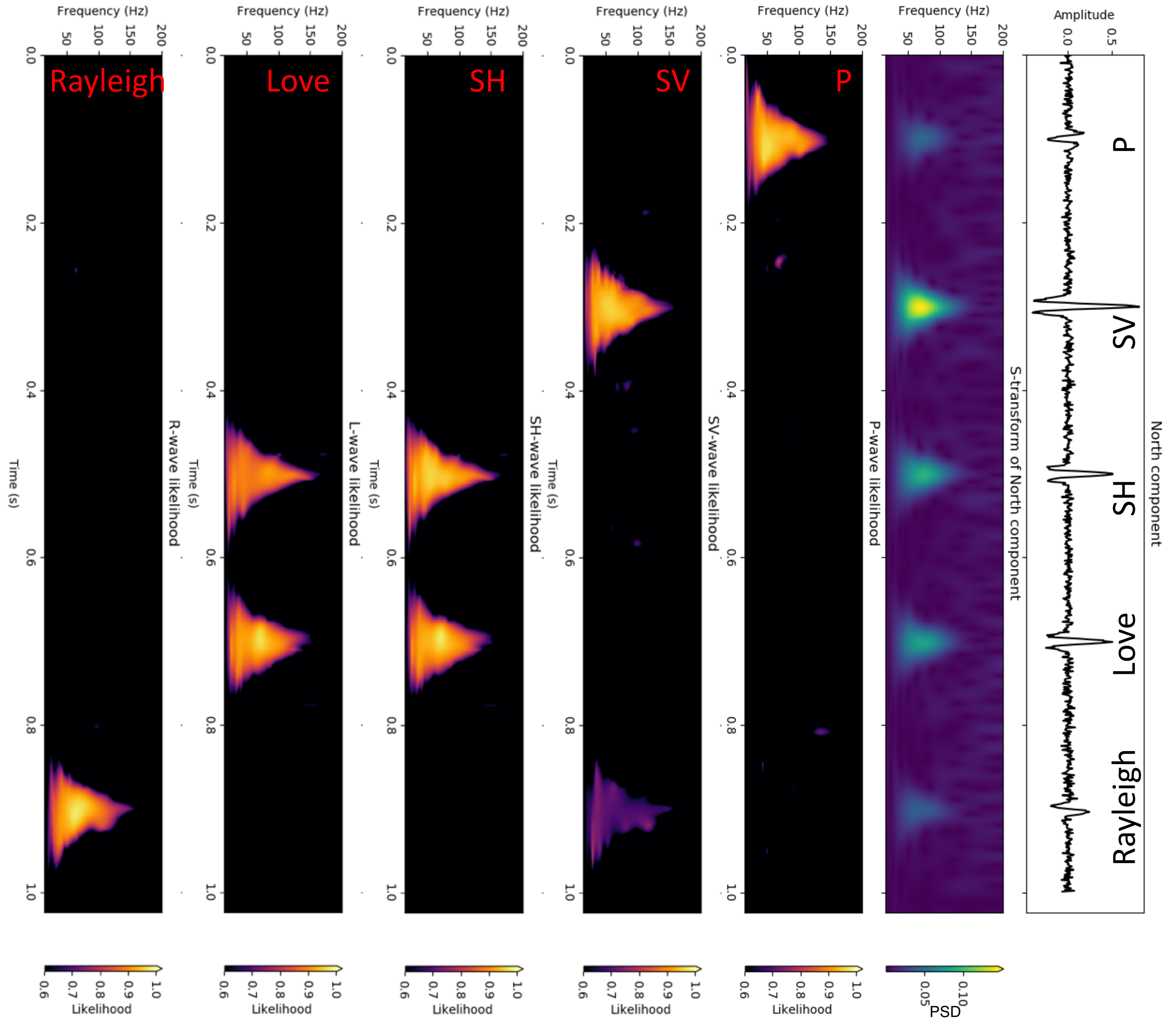
- Analysis breaks down, if more than two seismic phases overlap in time

- Varying noise levels on the individual components yield erroneous results



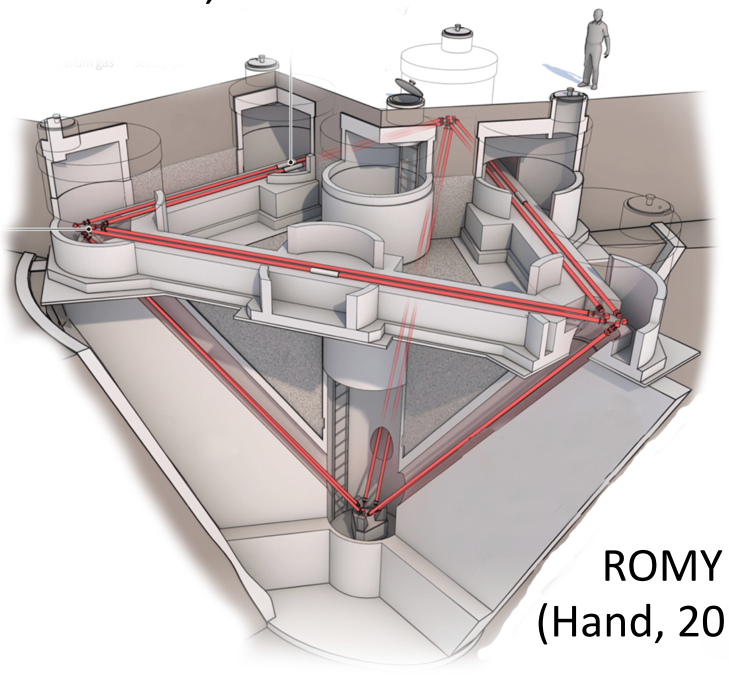
Synthethic test

- 6-C polarization analysis performed on time-frequency decomposed seismograms (S-transform) leads to more stable results due to the separation of different events in the frequency domain
- At each time-frequency pair, we seek to fit a 6-C polarization model (after Sollberger et al., 2018)
- Yields a probability from 0 to 1 that a certain wave type is present in the time-frequency decomposed seismogram (where 1 means the wave type is present)
- Note that it is not possible to distinguish Love from SH waves
- Currently Implemented estimators: Maximum likelihood, MUSIC, Dot product, Linear data projection
- The best-fitting model then also yields wave parameters, such as the phase velocity and the propagation direction
- The probability estimates can then be used to filter the spectrograms, the inverse S-transform then yields wave-type specific seismograms

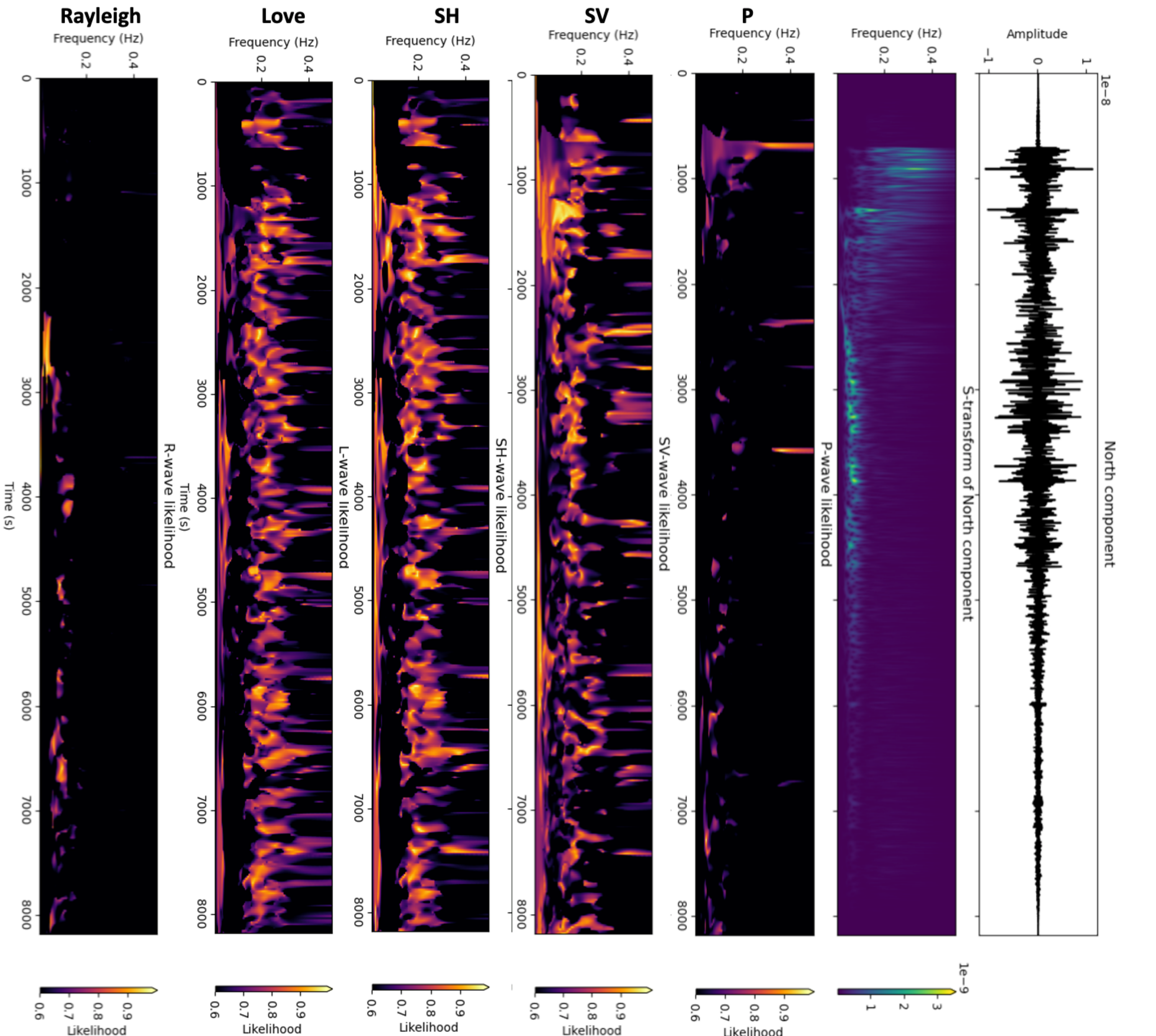


ROMY data

- ROMY: Large ringlaser gyroscope in Fürstenfeldbruck, Germany
- Recorded the January 2018, Gulf of Alaska earthquake
- Several events seem to be identified correctly: e.g., first-arriving P-wave, Rayleigh waves, S-wave arrival

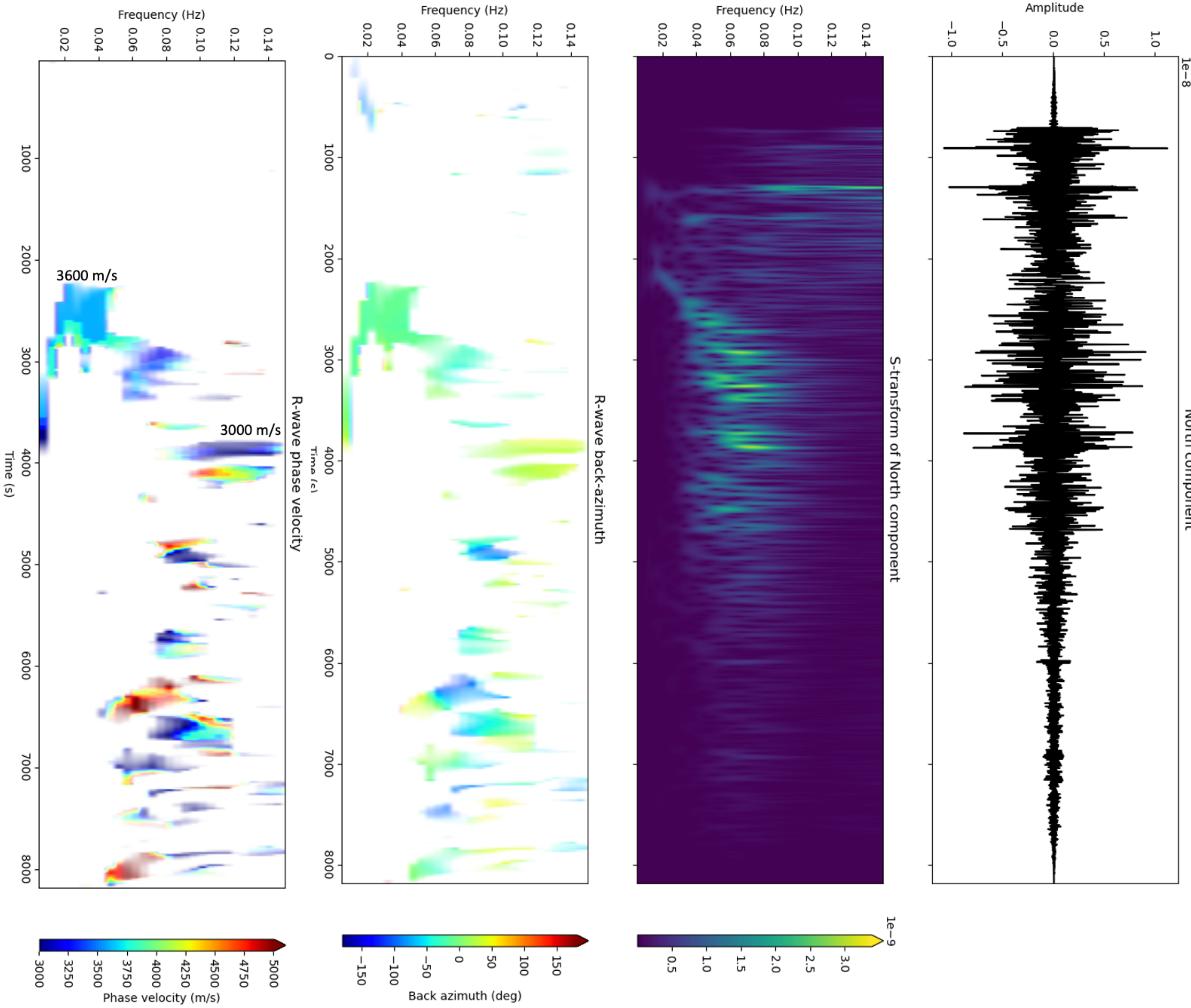


ROMY
(Hand, 2017)



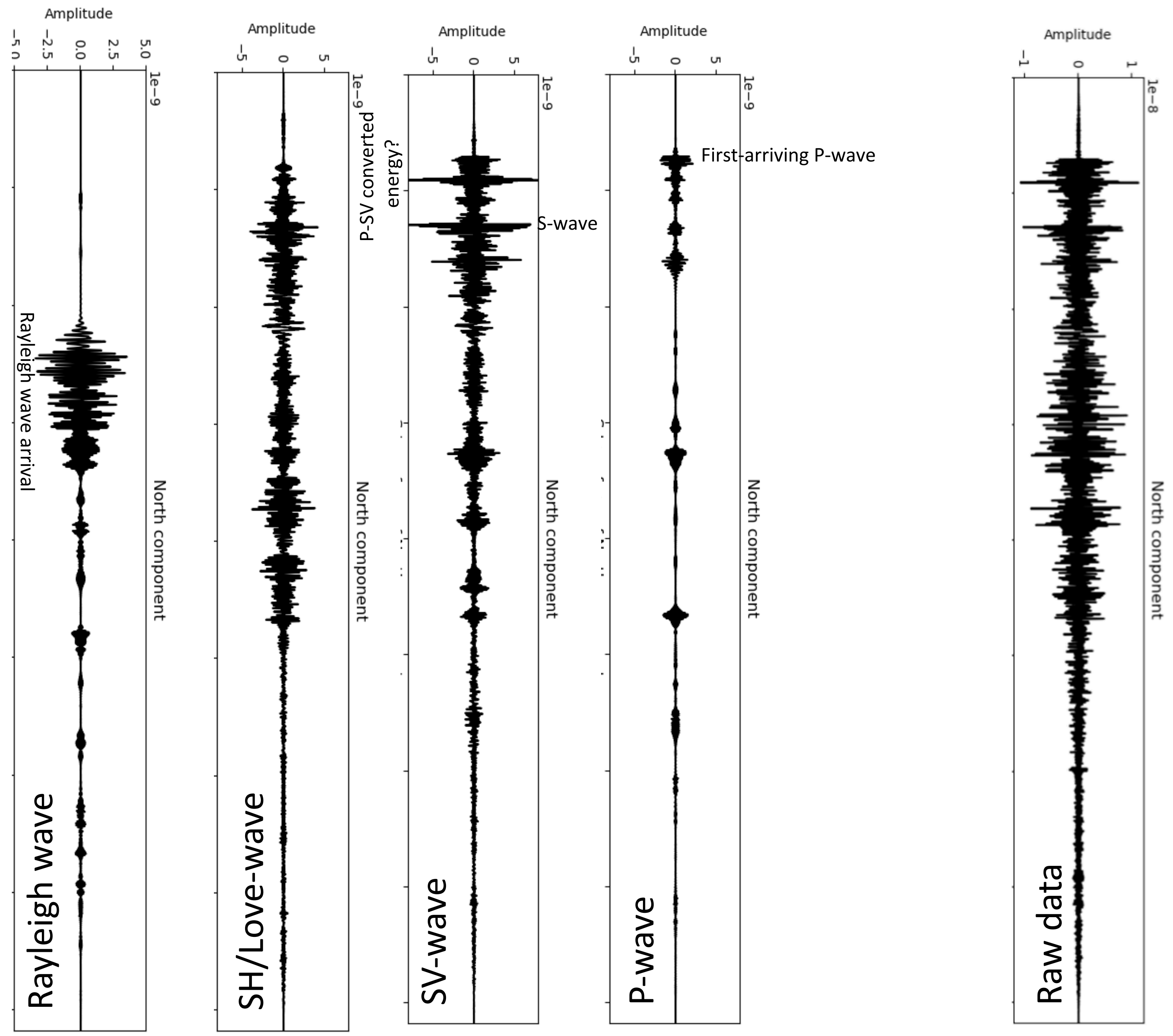
ROMY data – wave parameters

- Rayleigh wave example
- Wave parameters appear to be relatively stable
- Results are shown for Rayleigh-wave probability values > 0.8
- For the low frequencies, the back-azimuth nicely points to the epicenter (-15°), slight deviation for higher frequencies (-30°)
- Phase velocities start off with values of about 3.6 km/s and, as expected, decrease towards higher frequencies. Unfortunately, I ran into the lower bound of the prior at high frequencies (3000 m/s) so that the estimation at later times seems to get unstable
- Increasing the search-space would probably yield more stable results



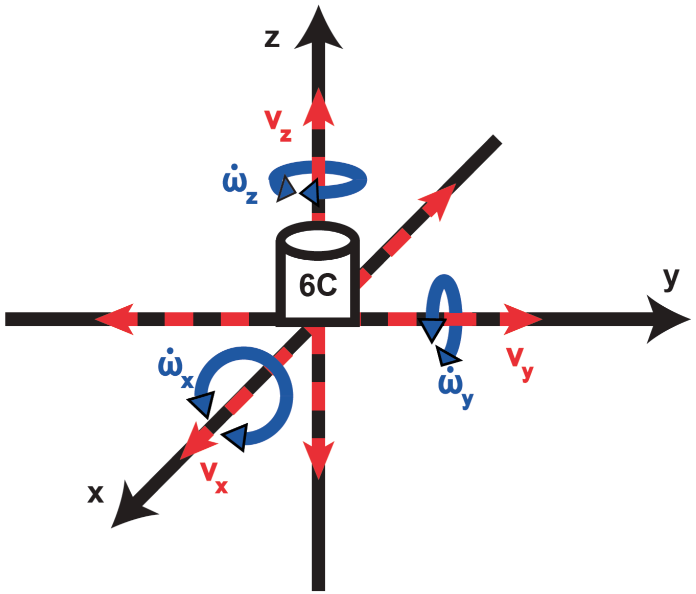
ROMY data – wave mode decomposition

- Fully automated wave-mode decomposition
- Spectrograms are filtered with the probability functions of each wave-type and brought to the time-domain using an inverse S-transform
- Yields separated, wave-type specific seismograms for all six components
- Shown is the horizontal (North) component -> dominated by shear wave modes
- Verification with synthetics underway



Conclusions

- 6-C polarization analysis allows automatically identify and separate seismic phases using just a single recording station
- Such analysis conventionally requires array processing techniques
- We foresee applications in:
  - Planetary seismology
  - Ocean bottom seismology
  - Alpine areas (where arrays are difficult to employ)



References

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