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Using arrival time difference to estimate Poisson ratio variations in the source region of earthquake swarms

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Crustal earthquake swarms are an expression of intensive cracking and rock damaging over periods of days, weeks or month in a small source region in the crust.
They are caused by longer lasting stress changes in the source region.
Often, the localized stressing of the crust is associated with fluid or gas migration, possibly in combination with pre-existing zones of weaknesses.
However, verifying and quantifying localized fluid movement at depth remains difficult since the area affected is small and geophysical prospecting methods often cannot reach the required resolution.

We develop a simple and robust method to estimate a Poisson ratio in the source region of an earthquake swarm. The Poisson ratio may be unusual large if the swarm is related to fluid or gas.
The method uses arrival time difference between P and S waves observed at surface seismic stations, and the associated double differences between pairs of earthquakes.
The approach may be viewed as a Wadati diagram method, modified to consider double differences. An advantage is that earthquake locations are not required and the method seems lesser dependent on unknown velocity variations in the crust outside the source region.
A disadvantage is that arrival times of both, P and S waves, are needed at a sufficient accuracy. Waveform cross correlation may thus be useful if the observed waveforms from different earthquakes are similar.

We present the theory of the method and synthetic test in 3D media.
First application concern two different processes:
(1) the study of natural earthquake swarms in NW-Bohemia at a depth of 8-10 kilometers that are possibly caused by magmatic intrusions.
(2) the study of a stimulation experiment at a depth of 4 km beneath the city of Basel, Switzerland, in order to enhance the permeability of the rock to produce hydrothermal energy.

Although the method only derives the Poisson ratio in the source region in comparison to the average ratio in the crust beneath the seismic network, it may be interesting for monitoring vp/vs changes within the earthquake swarm since the processing effort is small.