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Multiscale stress field inversion in the crust from focal mechanism datasets

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Earthquake focal mechanisms are an important tool to study spatial and temporal patterns of the stress field within the lithosphere. Nowadays various techniques are able to exploit focal mechanisms dataset to retrieve the orientation of the principal stress tensor axes and a ratio of their respective magnitudes (Bishop's ratio). However these techniques rely on the assumption of a homogeneous stress field responsible for the earthquakes. Within the Earth's lithosphere the stress field is highly variable depending on the geodynamic context, heterogeneities of the mechanical properties and time-varying perturbations (earthquakes, volcanic processes).
Various methods have been devised to effectively capture the complexity of the stress field. An important category relies on a clustering approach to identify different contributions to the heterogeneous dataset. However these techniques are effective only when the different stress field components are not so many and are well separated. Other techniques are more appropriated when dealing with smooth varying stress fields. They rely on a damped linearized inversion on a grid and allow imaging the spatial variations in the stress field.

We propose a novel approach based on a space-time 4D Discrete Wavelet representation of the stress field. The usage of Discrete Wavelets provides a natural framework to capture the multiscale nature of the stress field. We parameterize the spatial and temporal distribution of the stress field parameters using 4D wavelets, selecting only those constrained by a sufficient numbers of focal mechanisms. This allows reducing the computational efforts of the inverse methods, keeping a greater level of details in regions/intervals more constrained by the data. Using a linearized damped inverse method we are able retrieve the spatial and temporal pattern of the stress field simultaneously at different scales.
We show the performances of the method using both synthetic tests as well as example application to both volcanic and tectonic contexts.