

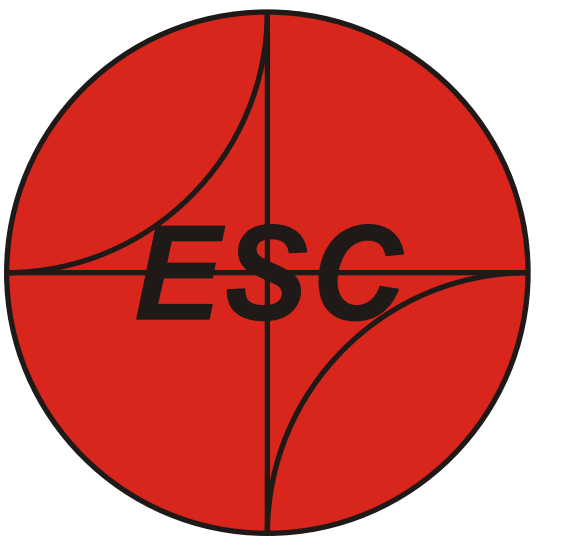


DYNAMIC STRESS FIELD OF ADVANCED KINEMATIC EARTHQUAKE SOURCE MODELS

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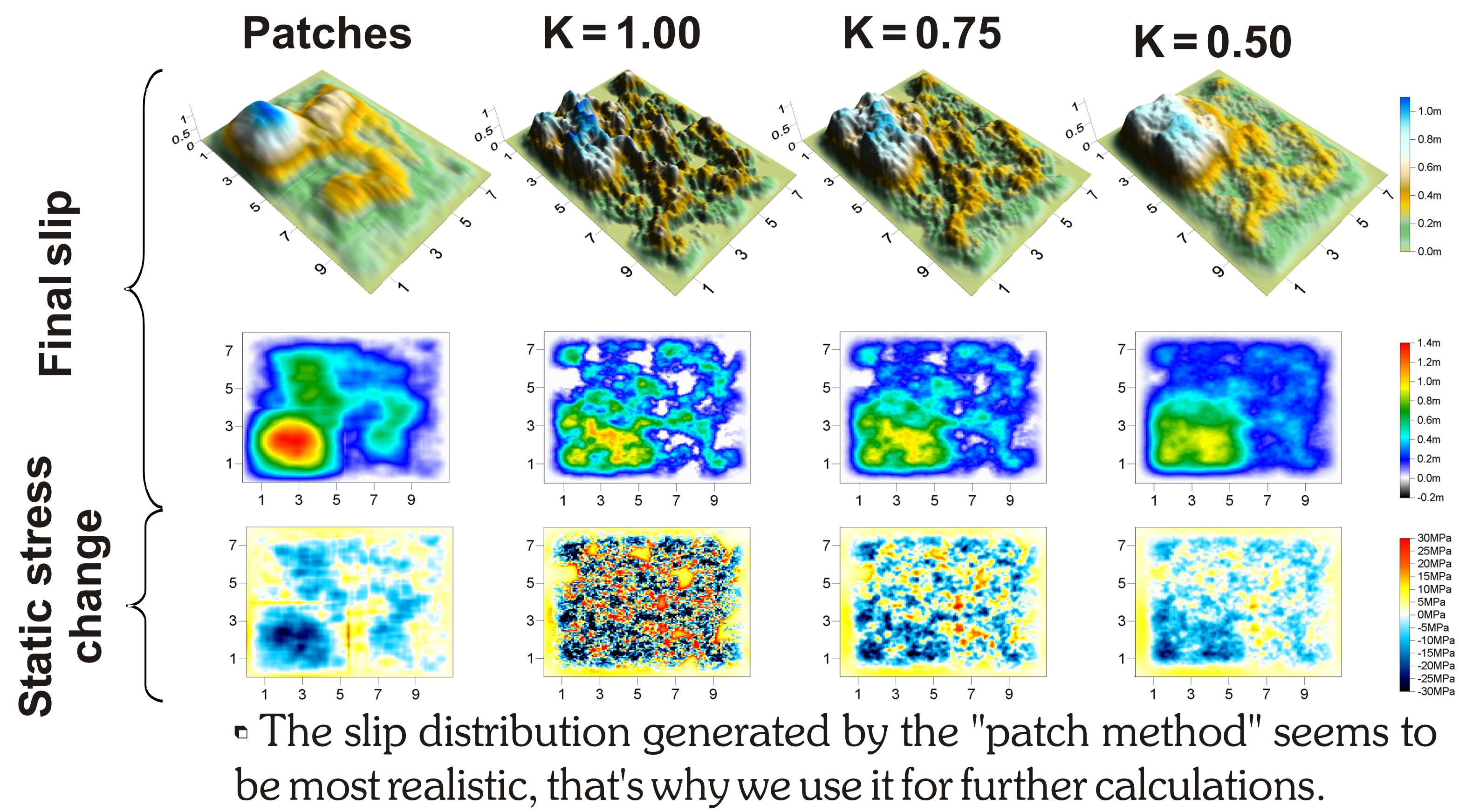
Abstract

Recently, advanced theoretical kinematic source models have been developed, since previous models lack complexity commonly observed in inversion studies of earthquake sources. Such theoretical models provide complex evolution of slip on a fault, together with more or less feasible radiated wave field which follows widely accepted omega-squared model. As these models are purely kinematic, they don't provide explicit constraints on parameters controlling the rupture dynamics. The aim of this study is to analyze the stress field on the fault associated with the prescribed slip history. Full dynamic stress history is calculated on the fault, using boundary integral method formulated in spectral domain (Bouchon, 1997). Basic characteristics of resulting stress field are inferred and discussed in relation to recent dynamic source models of real earthquakes. Particularly, we determine the static stress drop and make estimations of the strength excess and the slip weakening distance taking into account the slip weakening constitutive relation. Such analysis is performed for a number of slip functions sets. We have focused our study on k-squared model with k-dependent rise time, presented by Bernard et al. (1996) and generalized by Gallovic and Brokesova (2004). The different sets of slip functions are generated by varying the maximum rise-time, general shape of slip function, the slip pulse width, etc. As a result of this parametric study, we try to constrain free parameters of studied kinematic models from the dynamic point of view.

Kinematic k⁻² earthquake source model

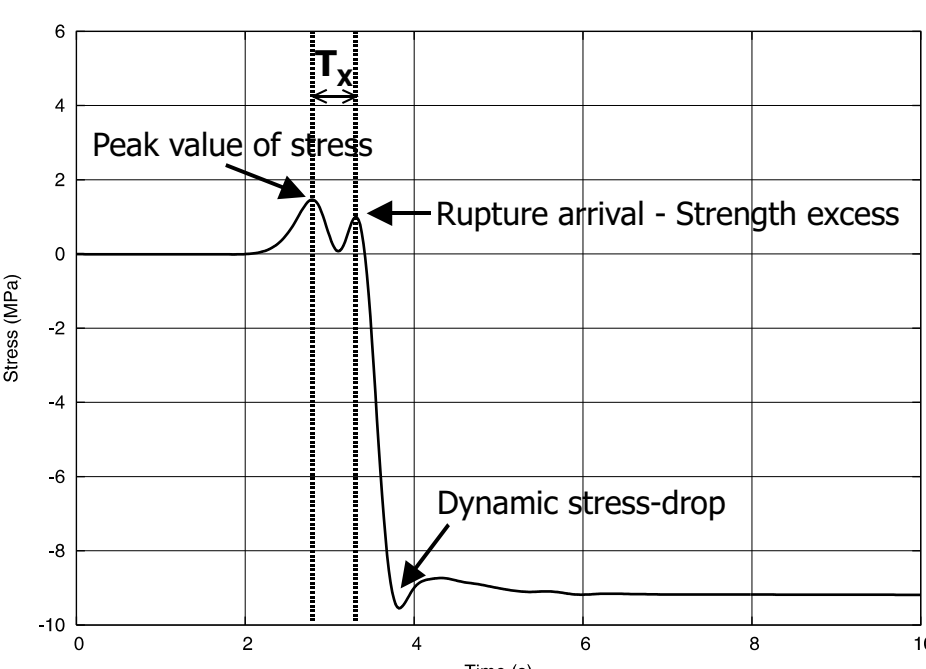
- Proposed by Herrero & Bernard (1994) and further developed by Bernard et al. (1996), Hisada (2000) and Gallovic & Brokesova (2004).
- radiation
- Constant rupture velocity (not necessary)
- Instantaneous slip or **k**-dependent rise time
- k**⁻² final slip distribution
 - Definition - spectral amplitudes of a final slip distribution decay as power of **2**.
 - How to generate stochastic **k**⁻² slip distribution?
 - By white noise filtering:
$$D(k_x, k_z) = \frac{\Delta \sigma L W}{\sqrt{1 + \left(\frac{k_x L}{2\pi} \right)^2 + \left(\frac{k_z L}{2\pi} \right)^2}} e^{i\Phi(k_x, k_z)}$$
 - By superimposing slip patches with appropriate scaling.

k⁻² model - static case

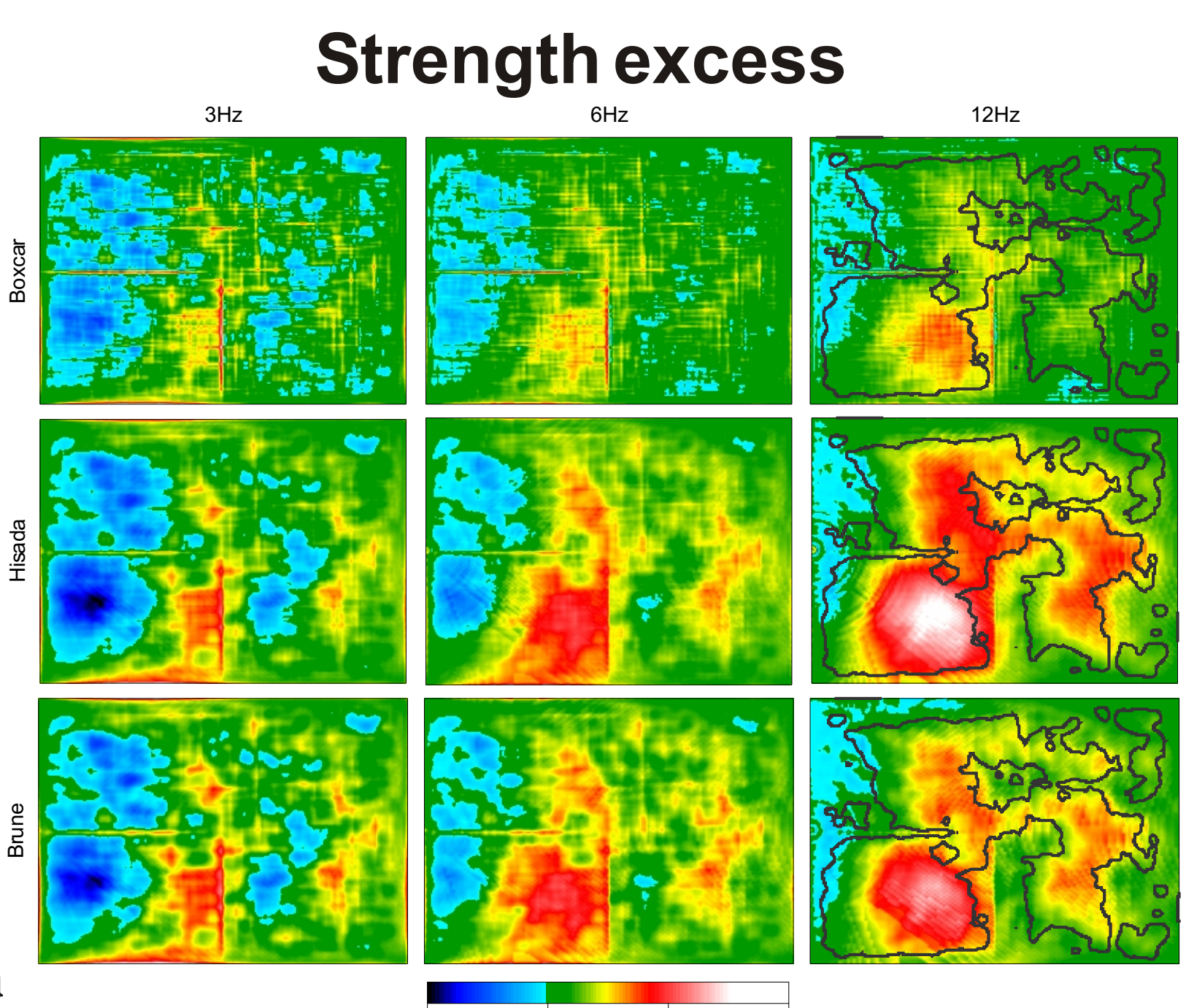


Interpretation of k⁻² model stress field

- We interpret dynamic stress histories using SW friction law. Method of SW parameters determination from stress time histories is figured below, resulting distributions are figured on left.
- An extra attention was payed to the influence of filtering, because it has an effect on determined values.



Comments on figure above: grey contours represent boundary between positive and negative static stress-drop values. Presented distributions show a strong correlation with these contours. **T_x** distributions reflect a correspondence with fracture mechanics (white areas are in an agree).



Mathematical formulation

- Equations:
$$\rho \ddot{\mathbf{u}} = \mathbf{f} + \nabla \cdot \boldsymbol{\tau}$$
$$\boldsymbol{\tau} = \lambda \nabla \cdot \mathbf{u} \mathbf{I} + \mu (\nabla \mathbf{u} + (\nabla \mathbf{u})^T)$$
- Boundary condition:
$$[\mathbf{u}]_{\pm}^+(\mathbf{x}, t), \mathbf{x} \in \Sigma(t)$$
- We seek:
$$\boldsymbol{\tau}(\mathbf{x}, t), \mathbf{x} \in \Sigma(t \rightarrow \infty)$$

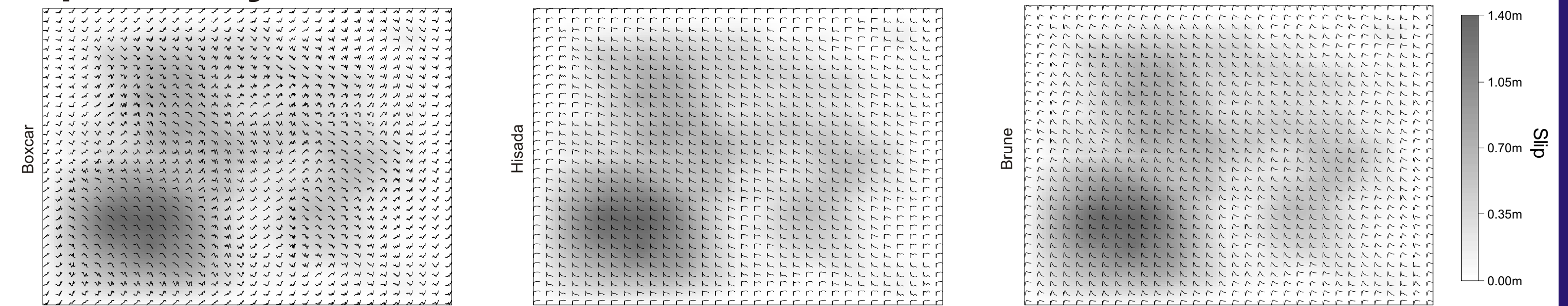
Solution

- We adopted **B**oundary **I**ntegral **E**lement **M**ethod (Bouchon, 1997).
- Finite fault is represented by 2D array of double-couple point sources.
- Elastic radiation from each point source is expressed as a double integral over wavenumbers (Weyl's integral) which is calculated by 2D discrete Fourier series - radiation from each point can be expressed as a double finite summation (so called **D**iscrete **W**avenumber method).
- Free of singularities, which are present in a number of time domain formulations of BIEM (Madariaga & Olsen, 2002).

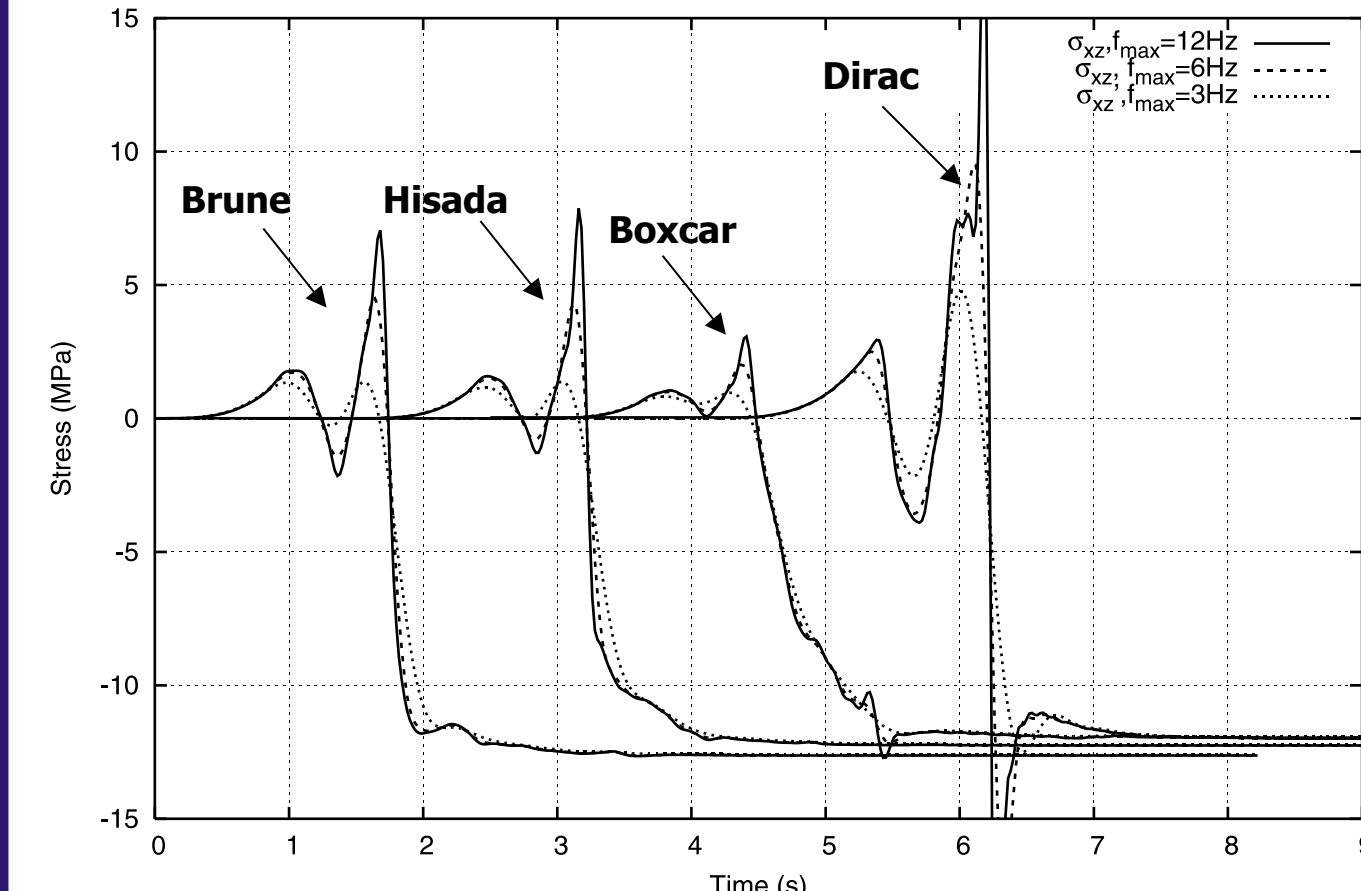
k⁻² model - dynamic case

- We have focused on the **k**⁻² model of Bernard et al. (1996), generalized by Gallovic & Brokesova (2004)
 - Constant rupture velocity
 - We choose four slip velocity functions:
 - Dirac -function, Boxcar, Brune's pulse, Hisada's function

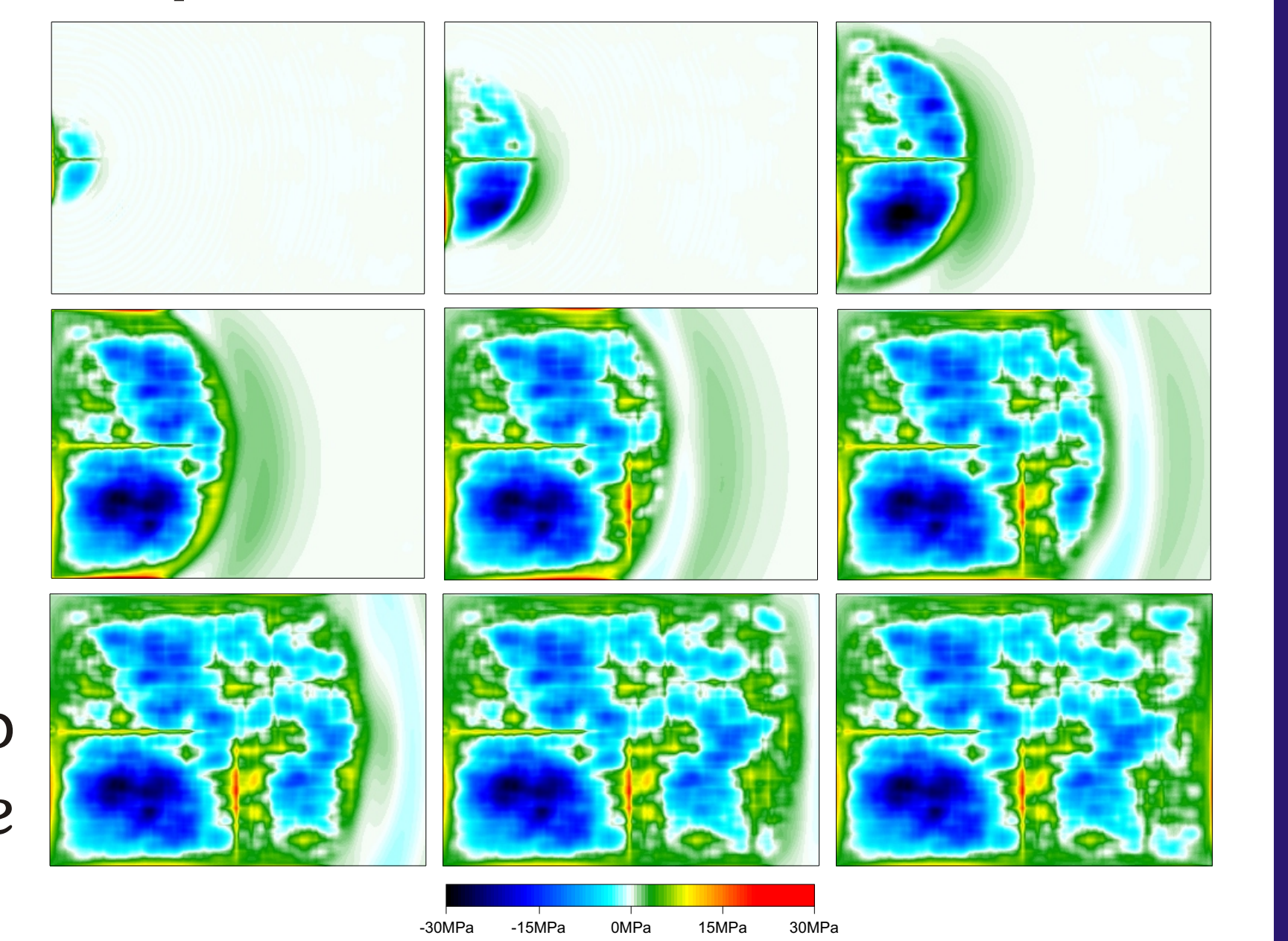
Slip velocity functions



Stress time histories

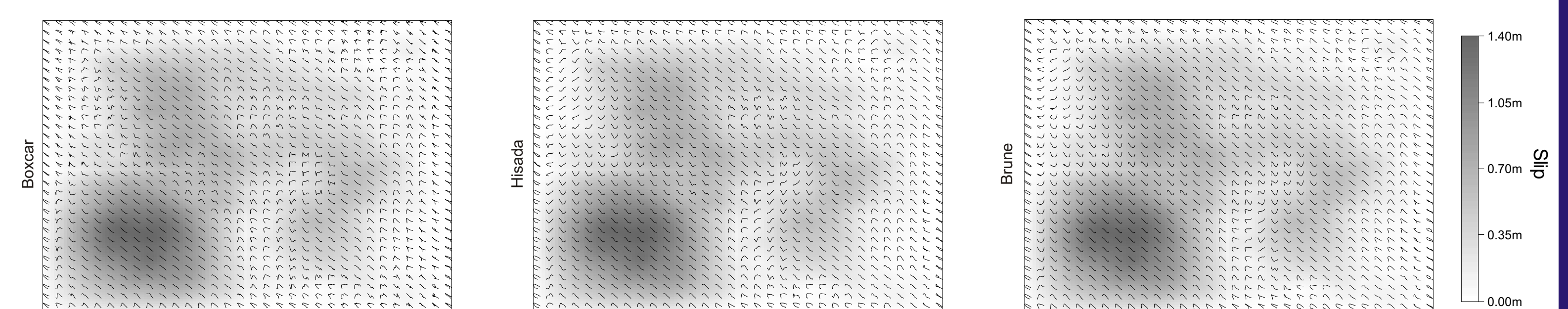


Snapshots of stress

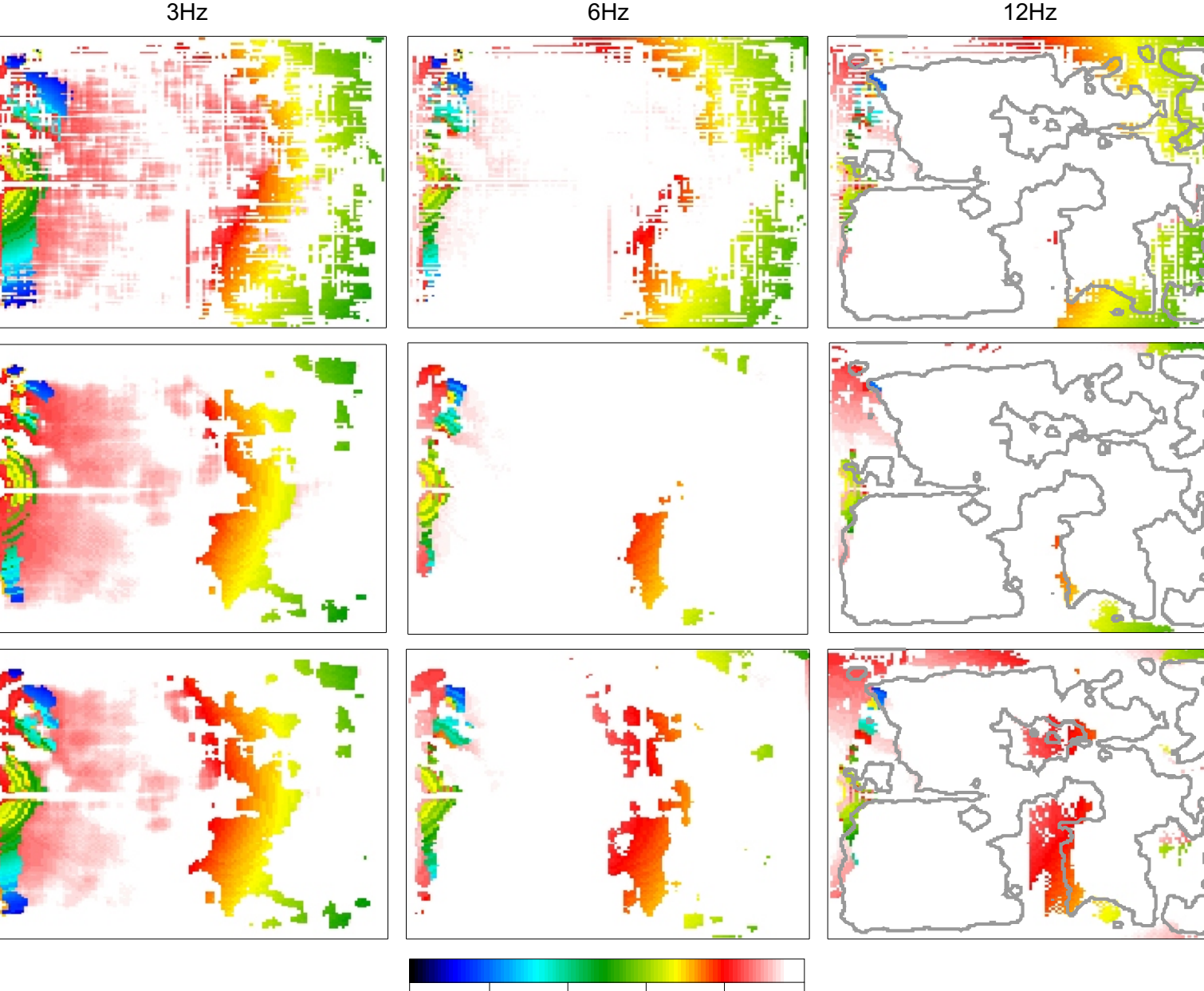


- An influence of different slip functions and filtering on stress time histories is shown in left top graph.
- An example of evolution of stress over fault is shown above (Hisada, 6Hz, 0.5s step). Stress vs. slip for same case is depicted below, such visualization has a meaning (see next frames).

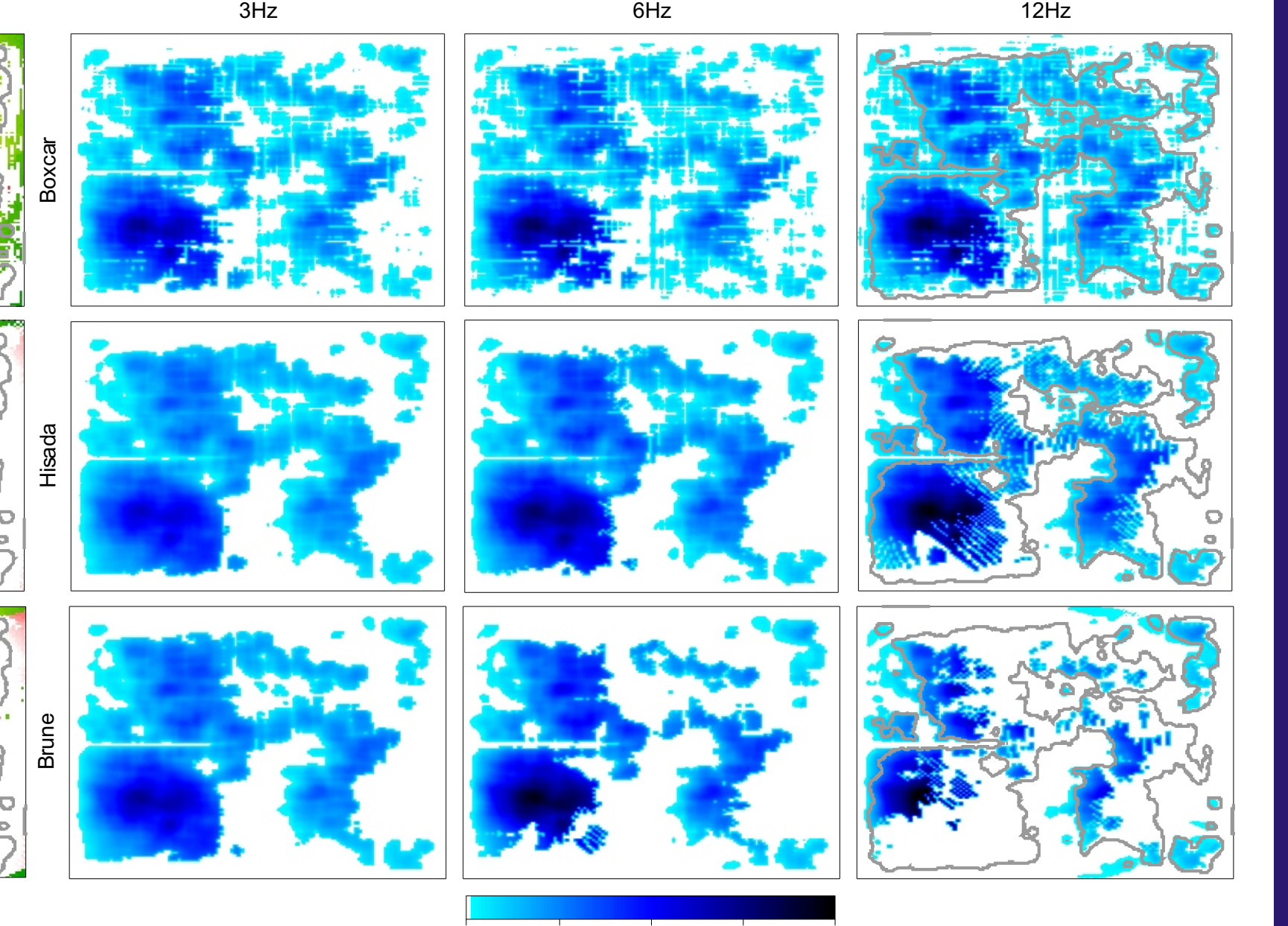
Stress vs. slip



T_x distribution



Dynamic stress-drop



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Discussion & Conclusions

- Models with slip functions having k-dependent rise time are free of singularities and neither of them is in clear contradiction to earthquake source dynamics.**
- Slip velocity function of Hisada type seems to be most appropriate, maybe because of the shape close to Kostrov's function.**
- Strength excess, dynamic stress-drop and T_x distribution exhibit correlation with static stress drop distribution in case of constant rupture velocity**
- Forward dynamic modeling is necessary to verify our estimations.**