Trans-dimensional finite-fault inversion of an earthquake jointly using seismic and geodetic data

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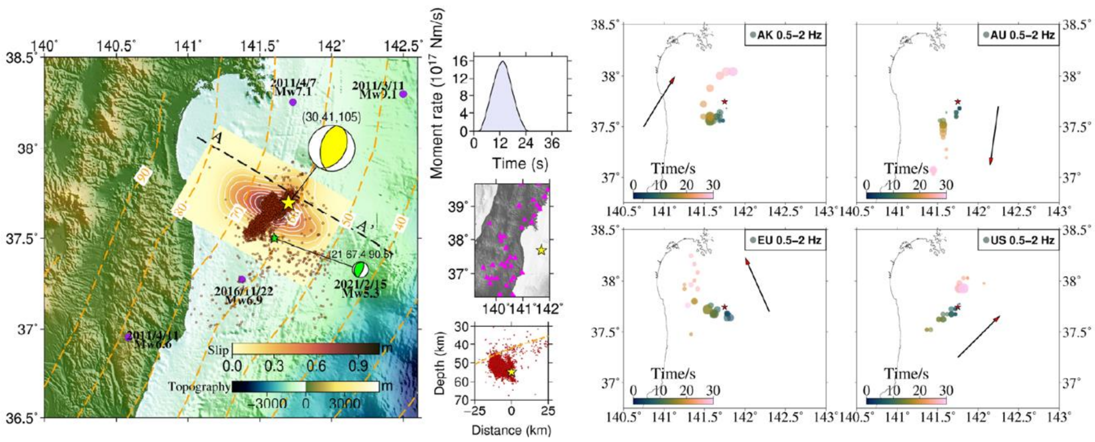
1. Introduction

During my stay at the Earthquake Research Institute (ERI), the University of Tokyo, I worked with Professor Aoki Yosuke in several projects, including the investigation of the rupture process of the 2021 Mw 7.1 Fukushima earthquake, the understanding and mitigating of the Spatial bias of Earthquake Source Imaging with Regional Slowness Enhanced Back-Projection and the development of trans-dimensional finite-fault inversion of an earthquake jointly using seismic and geodetic data.

2.1 Abstract of Project #1

We constructed an integrated rupture model of the 2021 Mw 7.1 Fukushima earthquake, an intraplate earthquake, by resolving both its spatiotemporal distribution of slip-rate and high frequency (~1 Hz) radiations. We analyzed near-field seismic observations using a novel finite fault inversion method that allows automatic parameterization and teleseismic data from multiple arrays using the MUSIC Backprojection (BP) method that enhances imaging resolution. The inverted slip distribution obtained from waveforms filtered in the frequency band of 0.02–0.2 Hz showed that the kinematic rupture propagated along both the strike (~35km), and dip directions (~85 km), and that the large-slip area was located southwest to the hypocenter with a maximum slip of ~1.03 m. Overall, no obvious frequency-dependent rupture behaviors occurred during the rupture process due to the deep nucleation of the Fukushima earthquake on a heterogeneous fault where sizes of asperities do not monotonically increase with depth, which sheds light on understanding the rupture dynamics of intraplate earthquakes in subduction zones.

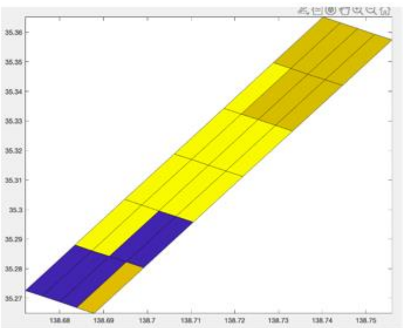


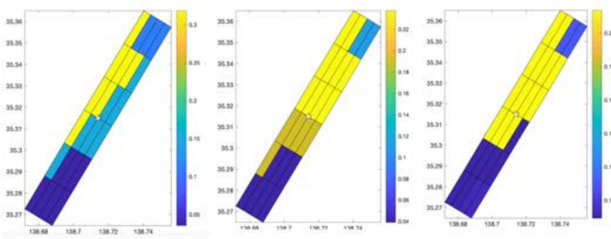
2.1 Abstract of Project #2

We investigate characteristics of spatial biases in the Back-projection method and the effectiveness of the Slowness Enhanced Back-projection (SEBP). The spatial bias refers to the location error in Back-projection caused by travel time errors due to 3D Earth structure. SEBP reduces such bias by calibrating the gradient of travel time (slowness) in the source. We first analyze 22 M4-M6 earthquakes in the Commander Island and find the amplitudes and directions of spatial biases follow distinct regional patterns. In light of this, we propose a regional SEBP approach that introduces spatially variable slowness correction. The regional SEBP in the Commander Island resulted in a ~ 50% reduction in the average length of spatial bias from ~20 km to ~10 km, which is more effective than the uniform SEBP that gives a 25% error reduction. We then analyze 109 M4-M7 earthquakes in the Tohoku region and also find a 50% error reduction by regional SEBP. This indicates that half of the spatial biases are aleatory uncertainties that are caused by regional structural complexity and can be calibrated with SEBP, while the residue errors are epistemic uncertainties that are random and caused by local velocity heterogeneities. With regional SEBP applied to the 2011 Tohoku earthquake, we find that high-frequency radiators did not reach beyond the down-dip limit of interplate seismicity, indicating that the coseismic slip unlikely penetrated into the brittle-ductile transition zone. Such observations suggest that the enhanced dynamic weakening mechanism due to thermal pressurization effects may not be activated during this event.

2.3 Abstract of Project #3

To flexibly and efficiently express fault-slip distributions of an earthquake in consideration of the complicated uncertainties due to observational data and model parameters, we aim to establish a trans-dimensional fault-slip inversion system based on the Iterative deconvolution and stacking (IDS) method to adaptively meshes the fault lane for spatially varying resolution with the combination of geodetic and seismic data.





With the weight of the smoothing constraints increasing from the left to right, the first-order characteristics of rupture process keep unchanged.