Contribution ID: **14**

Type: **not specified**

Estimation of the fault slip of short-term slow slip events from GNSS data using deep learning

Wednesday, 25 October 2023 11:00 (30 minutes)

Since dense geodetic and seismic networks reveal the presence of slow earthquakes and the close relationship between regular and slow earthquakes, many studies have focused on the detection of slow earthquakes and their source characterization. Global Navigation Satellite System (GNSS) continuously monitors ground deformation and is one of the most common tools used to detect slow slip events (SSEs), a kind of slow earthquake. However, GNSS data sometimes needs manual preprocessing due to its low signal-to-noise ratio. Furthermore, automated analysis methods are becoming increasingly important in today's world of huge data volumes. Deep-learning approaches, especially convolutional neural networks (CNN), have largely contributed automation process to deal with big data. These brand-new technologies have brought significant breakthroughs into many fields including seismology (e.g., Yano et al., 2021) and geodesy (e.g., Rouet-Leduc et al., 2021).

In this study, we aim to develop a deep-learning method to monitor spatio-temporal evolutions of short-term SSEs based on a dense GNSS network. We theoretically create two types of horizontal deformation data including synthetic noise by assuming 272 subfaults in western Shikoku, southwest Japan; 16 subfaults along the strike multiplied by 17 subfaults along the dip. One is deformations at 113 GNSS stations, and the second is those at 900 virtual stations which are regularly located over the target area. We tailor two supervised-learning Convolutional Neural Network (CNN) models to estimate the slip area and the slip amount of SSE by learning those deformation images as input data. Nakagawa et al. (2021, Fall Meeting in Geodetic Society of Japan) showed that the model trained with GNSS stations estimated SSEs with 91.8% variance reduction (VR) while the other model achieved 98.3% VR. We concluded that this difference in estimation accuracy is contributed to the dissimilarity between input deformation images. Therefore, we newly implement Model-supervised Interpolation (MSI) approach to overcome this problem. MSI successfully reproduces the deformations at 900 virtual stations only from the deformations at GNSS stations with 97.4% VR although nearly half of the target area is located on the offshore region. It shows this deep-learning approach is effective to estimate SSEs from GNSS data in this region.

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Session Classification: Session: Earthquake Hazard