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Deep learning prediction of measured earthquake waveforms from synthetic data

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Seismic waveforms of teleseismic earthquakes are highly complex since they are a superposition of numerous phases that correspond to different wave types and propagation paths. In addition, measured waveforms contain noise contributions from the surroundings of the measuring station. The regional distribution of seismological stations is often relatively sparse, in particular in regions with low seismic hazard such as Northern Germany. However, a detailed knowledge of the seismic wavefield generated by large earthquakes can be crucial for highly precise measurements or experiments that are carried out for instance in the field of particle physics, where seismic wavefields are considered noise. While synthetic waveforms for cataloged earthquakes can be computed for any point on the Earth's surface, they are based on a highly simplified Earth model. As a first step towards the prediction of a dense seismic wavefield in a region with sparsely distributed stations, we propose to train a convolutional neural network (CNN) to predict measured waveforms of large earthquakes from their synthetic counterparts. For that purpose, we compute synthetic waveforms for numerous large earthquakes of the past years with the IRIS synthetics engine (Syngine) and use the corresponding actual measurements from stations in Northern Germany as labels. Subsequently, we test the performance of the trained neural network for events not part of the training data. The promising results suggest that the neural network is able to largely translate the synthetic waveforms to the more complex measured ones, indicating a means to overcome the lack of complexity of the Earth model underlying the synthetic waveform computation and paving the way for a large-scale prediction of the seismic wavefield generated by earthquakes.