A deep-learning approach to three-dimensional precipitation nowcasting

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The Phased-Array Weather Radar (PAWR), developed by the National Institute of Information and Communications Technology, Osaka University, and Toshiba Corporation, has been in operations since 2012 in Japan. The PAWR scans the whole sky in the 60-km range every 30 seconds at 110 elevation angles. Four PAWRs of the same type have been installed at Osaka, Kobe, Okinawa, and Tsukuba, and two similar ones of other types have been installed in Japan. Taking advantage of the PAWRs' frequent and dense three-dimensional volume scans, we have been operating 30-second-update three-dimensional precipitation nowcasting at RIKEN since 2017 (Otsuka et al., 2016). Our current system adopts an optical-flow-based algorithm in the three-dimensional space; its computational cost is orders of magnitude higher than the traditional two-dimensional optical flow. In addition, convective clouds evolve rapidly within a 10-minute forecast, sometimes violating the assumption of Lagrangian persistence.

Recent advances in the machine-learning algorithms may help solve these problems. In this study, a three-dimensional extension of the Convolutional Long Short-Term Memory (Conv-LSTM; Shi et al., 2015), a kind of deep-learning algorithm, is applied to PAWR nowcasting. First, radar data are converted onto a three-dimensional Cartesian coordinate with a grid spacing of 250 m in the horizontal and vertical. Training samples are taken from Kobe PAWR observations on 31 May, 26 July, and 27 July 2018. The K-means approach is used to extract rainy samples with a size of 61 x 61 x 9 pixels. 3500 samples are used for training, and 300 samples for test.

The three-dimensional Conv-LSTM successfully made predictions of convective storms; in some cases, intensification and weakening of precipitation that were not predicted by the optical-flow were well predicted. Statistical analyses showed that the Conv-LSTM-based system outperformed the optical-flow-based system. Further verification is needed under various conditions because machine-learning algorithms are not supposed to make reliable predictions under conditions that we have not experienced before.

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