Precipitation Retrievals from Millimeter-Wave Communications Satellite Links with Deep Generative Adversarial Networks

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Recently, there has been significant research interest in the opportunistic use of commercial microwave and communications satellite links to obtain rainfall estimates in regions that are outside the coverage of conventional weather radars. There are far more ground satellite terminals distributed across the world than weather radars. Further, the status of terminal link conditions, which are influenced by signal attenuation due to propagation in precipitation, are available in real-time at a central location. This set-up has, therefore, immense potential in harnessing useful rainfall information.

In general, communications user terminals (UTs) provide measurements of only carrier-to-noise-ratio (C/N) or specific attenuation *A*, thereby allowing derivation of rain rate *R* using the linear *R*-*A* relation. Such an estimate of rainfall does not take into account variations due to wind shear, storm type (convective/stratiform) and rain intensity (light/heavy). Unlike weather radars, UTs cannot provide products like reflectivity, Doppler velocity or dual-polarized moments that could be useful to delineate various storm situations.
In the absence of such useful information, our previous work demonstrated that machine and deep learning techniques are very effective in estimating rain-rates from just C/N measurements. We showed that a deep long short-term memory (LSTM) network, trained with the nearest weather radar or rain-gauge data, could learn to recognize rain intensities needed to suitably apply *R*-*A* formulae. However, LSTM being a supervised learning technique does not generate a new class that is different than the training stage.

In this work, we employ a deep generative adversarial network (GAN) to estimate rainfall through C/N data collected from 35 UTs located in a certain region in Germany. GAN is a recently proposed semi-supervised framework that teaches a deep learning model to interpret the underlying distribution of training data and then generate new samples from the same distribution. In tasks where estimation or generation of new classes is preferred over categorization into known classes, GAN offers exciting opportunity over other deep networks such as LSTM or convolutional neural networks (CNNs). We compare our results with the observations from the rain gauges and the nearest German weather service Deutscher Wetterdienst (DWD) radars.

The attached figure shows the location of 35 satellite terminals in Germany used in this study. The shaded box represents about 25 sq km area. The red dot indicates location of the nearest DWD radar

Keywords: Opportunistic weather monitoring, Satellite Communications, Deep Learning, Generative Adversarial Networks, Millimetre Wave, Real time data

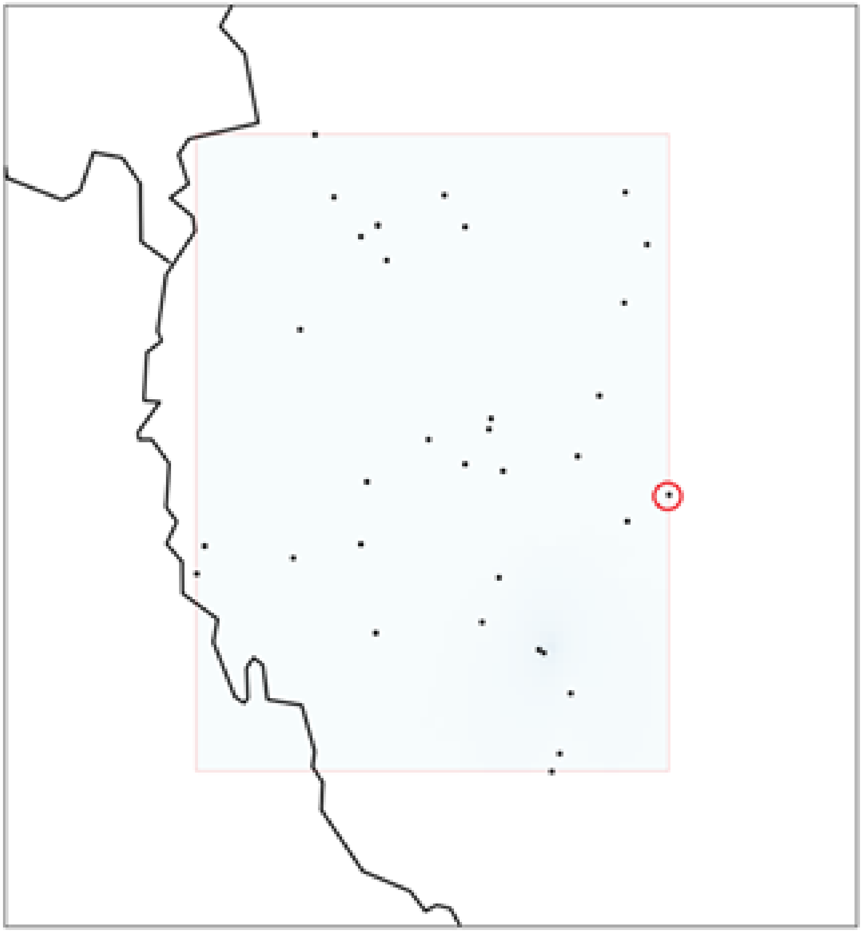

Figure 1. Location of 35 satellite terminals in Southwest Germany used in this study. The shaded box represents 25 km by 20 km area. The red dot indicates location of the nearest DWD radar.