A Data Fusion System for Accurate Precipitation Estimation Using Satellite and Ground Radar Observations: Urban Scale Application in Dallas-Fort Worth Metroplex

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Abstract

The space-based precipitation products are commonly used for regional and/or global hydrologic modelling and climate studies. However, the accuracy of onboard satellite measurements is limited due to the spatial-temporal sampling limitations, especially for extreme events such as very heavy or light rain. On the other hand, ground-based radar is more mature science for quantitative precipitation estimation (QPE). Nowadays, ground radars are critical for providing local scale rainfall estimation for operational forecasters to issue watches and warnings, as well as validation of various space measurements and products. This paper introduces a neural network based data fusion mechanism to improve satellite-based precipitation retrievals by incorporating dual-polarization measurements from ground-based dense radar network. The prototype architecture of this fusion system is detailed. Results from urban scale application in Dallas-Fort Worth (DFW) Metroplex are presented.

1. Summary

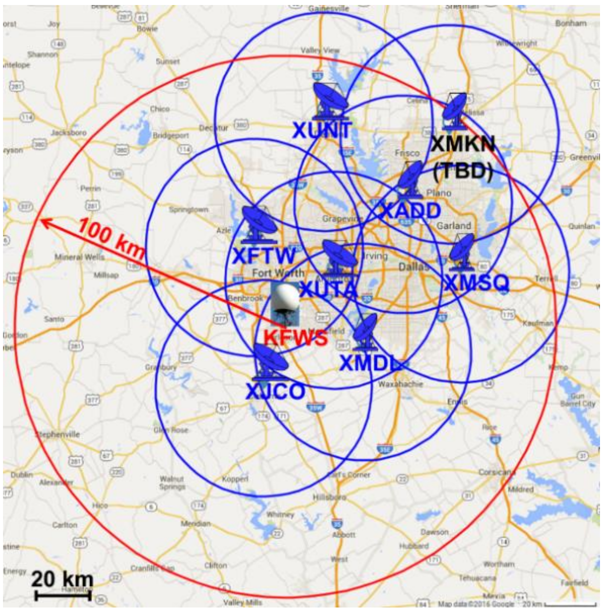

Figure 1. The layout of dual-polarization X-band radars (blue circles) and S-band KFWS WSR-88DP radar (red circle) over DFW Metroplex (from reference [4]).

Precipitation estimation based on satellite observations has been an important topic in satellite meteorology for decades. Up to the writing, a number of precipitation products at different space time scales have been developed based upon satellite measurements. One of the commonly used satellite precipitation products is produced using the CPC Morphing technique (CMORPH) [1], which is essentially derived based on geostationary satellite Infrared (IR) brightness temperature information and precipitation retrievals from low-earth-orbit passive microwave (PMW) measurements [2]. Although the space-based precipitation products provide an excellent tool for study of the global water cycle and climate properties, its accuracy is restricted due to the limitations of spatial-temporal sampling and the parametric retrieval algorithms.

Ground-based radar is more mature science for quantitative precipitation estimation (QPE), especially after the implementation of dual-polarization technique and further enhanced by urban scale radar networks. Since 2012, the center for Collaborative Adaptive Sensing of the Atmosphere (CASA) has been operating a high-resolution dense urban radar network in Dallas-Fort Worth (DFW) Metroplex [3,4]. Fig. 1 illustrates the layout of radars in this dense urban radar network. Fig. 2 shows the high-resolution real-time QPE system designed for this urban radar network. The DFW QPE system is based on fusion of polarimetric observations from both the X-band radar network, and the S-band KFWS WSR-88DP radar. The specific radar rainfall algorithms, as well as the fusion methodology combining observations at different temporal resolution are presented in [5]. The excellent performance of DFW QPE system has been demonstrated during several years of operation in a variety of precipitation regimes. The real-time rainfall products are used extensively for localized hydrometeorological applications such as urban flash flood forecasting.

Fig. 3 shows the probability distribution functions (PDFs) of rainfall rates derived from CMORPH and the DFW QPE system for the event of 29 May 2015. It can be seen that compared to ground radar network based rainfall products both the light rain and heavy rain regions are underestimated by CMORPH. To this end, this paper aims to improve space-based precipitation retrievals using the high-quality high-resolution radar rainfall estimates.

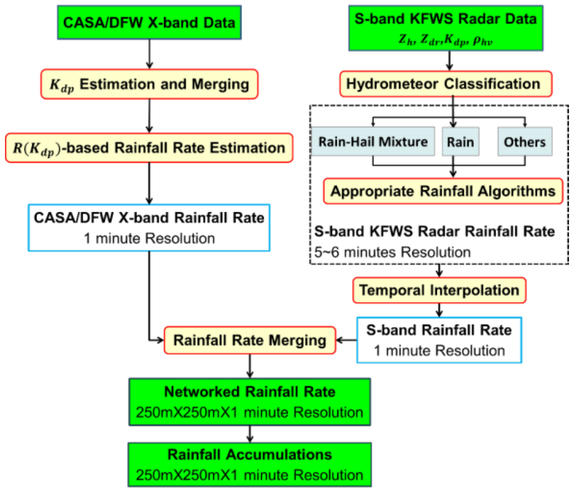

Figure 2. The quantitative precipititon estimation system for DFW desnse radar network.

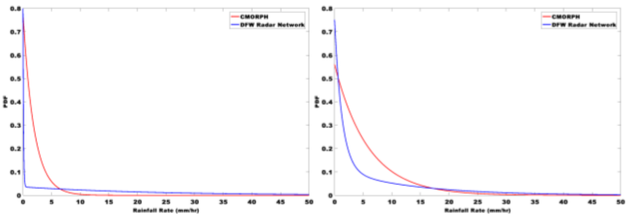

Figure 3. Probability distribution function (PDF) of rainfall rates derived from CMORPH and ground radar based QPE system for the event of 29 May 2015. (left) light-moderate rain, (right) moderate-heavy rain.

In particular, a multi-layer perceptron system is developed to improve satellite-based rainfall estimation using DFW radar rainfall products. Fig. 4 illustrates the fusion system framework combining both satellite and ground radar network observatoins. As shown in Fig. 4, the CMORPH methodology is first applied to derive combined PMW rainfall estimates and combined infrared (IR) data from a number of satellites. The combined PMW and IR data then serve as input of the proposed multi-layer perceptron model. The high-quality DFW rainfall products are used as target to train the model.

This paper details the multi-layer perceptron model and its training processing with a large number of precipitation events over the DFW Metroplex. The trained model will be evaluated using existing CMORPH products and surface rainfall measurements from gauge networks during independent (testing) precipitation events.

2. Acknowledgements

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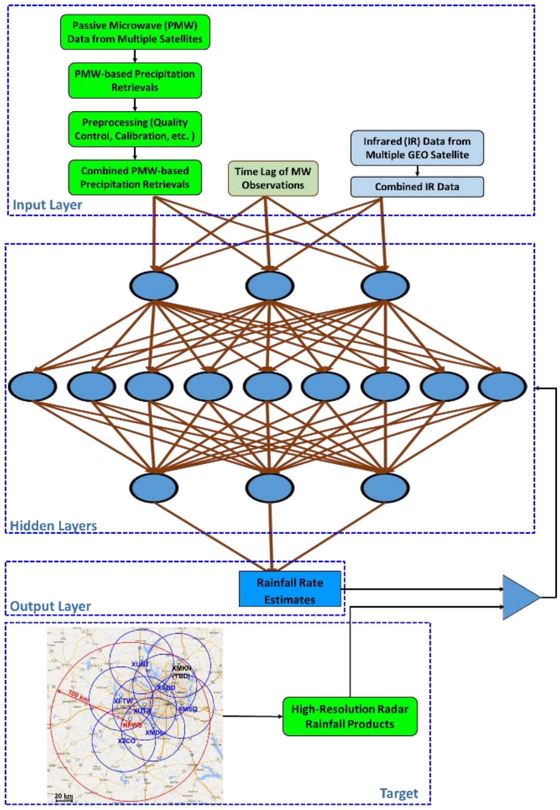

Figure 4. The fusion system for rainfall estimation using satellite and ground radar network observations.

3. References

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