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Correcting temporal sampling error in radar-rainfall: Effect of advection parameters and rain storm characteristics on the correction accuracy

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SUMMARY

This study offers a method to correct for the radar temporal sampling error when determining radar-rainfall accumulations. The authors evaluate the correction effect with respect to multiple factors associated with storm advection, rainfall characteristics, and different rainfall accumulation time scales. The advection method presented in this study uses linear interpolation of static rain storm locations observed at two intermittent radar sampling times to correct for the missed rainfall accumulations. The advection correction is applied to the high space (0.5 km) and time (5-min) resolution radar-rainfall products provided by the Iowa Flood Center. We use the ground reference data from a high quality and high density rain gauge network distributed over the Turkey River basin in Iowa to evaluate the advection corrected rain fields. We base our evaluation on six rain events and examine the correction performance/improvement with respect to the advection discretization, spatial grid aggregation, rainfall basin coverage, and conditional average rainfall intensity. The results show that the 1-min advection discretization is sufficient to represent the observed distribution of storm velocities for the presented cases. Grid aggregation that is motivated by the need to expedite the computation may induce errors in estimating advection vectors. The authors found that while the advection correction tends to enhance the QPE accuracy for intense rain storms over small or isolated areas, it has little impact on the improvement of light rain estimation.

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1. Introduction

Using a process known as Quantitative Precipitation Estimation (QPE), hydrologists have frequently used weather radar to estimate rainfall intensity and accumulation. Such estimates, developed at high spatial and temporal resolution, provide input to hydrologic flood-forecasting models. There are a number of uncertainty sources affecting radar QPE (for recent review, see Villarini and Krajewski, 2010), and the mitigation of these effects to reduce uncertainty in QPE has been a major goal in radar hydrology (e.g., Krajewski and Smith, 2002; Berne and Krajewski, 2013).

It has been acknowledged that radar-rainfall accumulations generated by weather radars from periodic sampling often incorrectly represent actual rain fields (e.g., Harrold et al., 1974; Wilson and Brandes, 1979; Huebner et al., 1986; Fabry et al., 1994; Liu and Krajewski, 1996). Some have even claimed that the effect from this temporal sampling error is more significant than the total error from other sources combined, particularly when using high spatial resolution data (e.g., Fabry et al., 1994). During the past twenty years, researchers have attempted to correct the error and improve the quality of rainfall estimates (e.g., Fabry et al., 1994; Liu and Krajewski, 1996; Anagnostou and Krajewski, 1999; Shapiro et al., 2010; Atencia et al., 2011). However, most of these researchers studied the correction performance exclusively through simulation, and there remains a need for an extensive evaluation based on actual observations from in-situ data.

There are good reasons for the difficulty of evaluation. First, there are intricate combinations of radar scanning frequency, storm velocity, and product grid resolution that contribute to the problem (see Fig. 1). For slow moving storms and coarse resolution data, even infrequent scanning may not produce significant errors. On the other hand, the recent trend to provide high-resolution products (e.g., 0.5 km in Krajewski et al., 2013 and 1.0 km in Zhang et al., 2011) that capitalize on the enhanced processing capabilities of modern computers exacerbates the problems for fast-moving storms. Fig. 2 shows an accumulation example of a high resolution (0.5 km) rainfall product that was created by the Iowa Flood Center (IFC). This 1-h accumulation map clearly shows spatially discontinuous rainfall patterns that were caused by the intermittent radar scanning frequency, as illustrated in Fig. 1 (we describe the details of the IFC product in Section 2). Another reason

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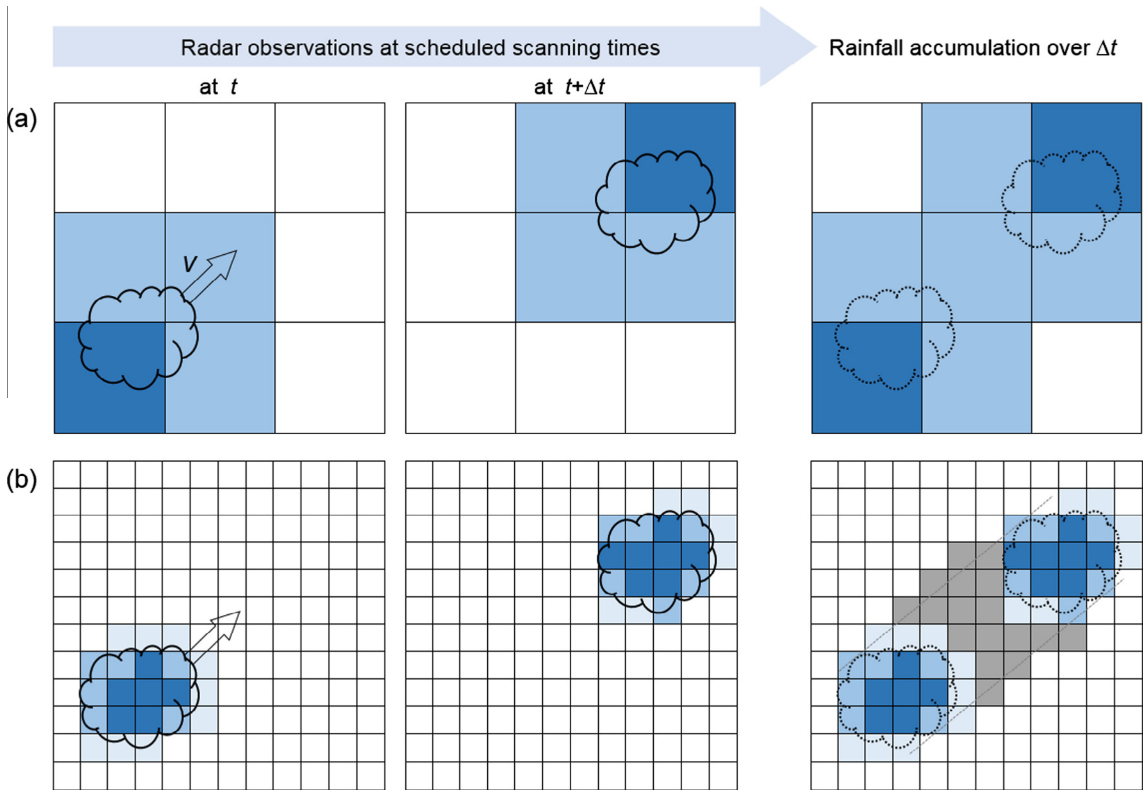

Fig. 1. Schematic representation of radar-rainfall accumulation with (a) coarse and (b) high resolution grids. Blue-colored grid pixels indicate estimated rainfall over the radar scanning interval (Δt), and gray-colored pixels in the high resolution plane illustrate missed rainfall locations due to periodic sampling. The shown accumulation error also depends closely on the radar scanning frequency and storm velocity (V). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

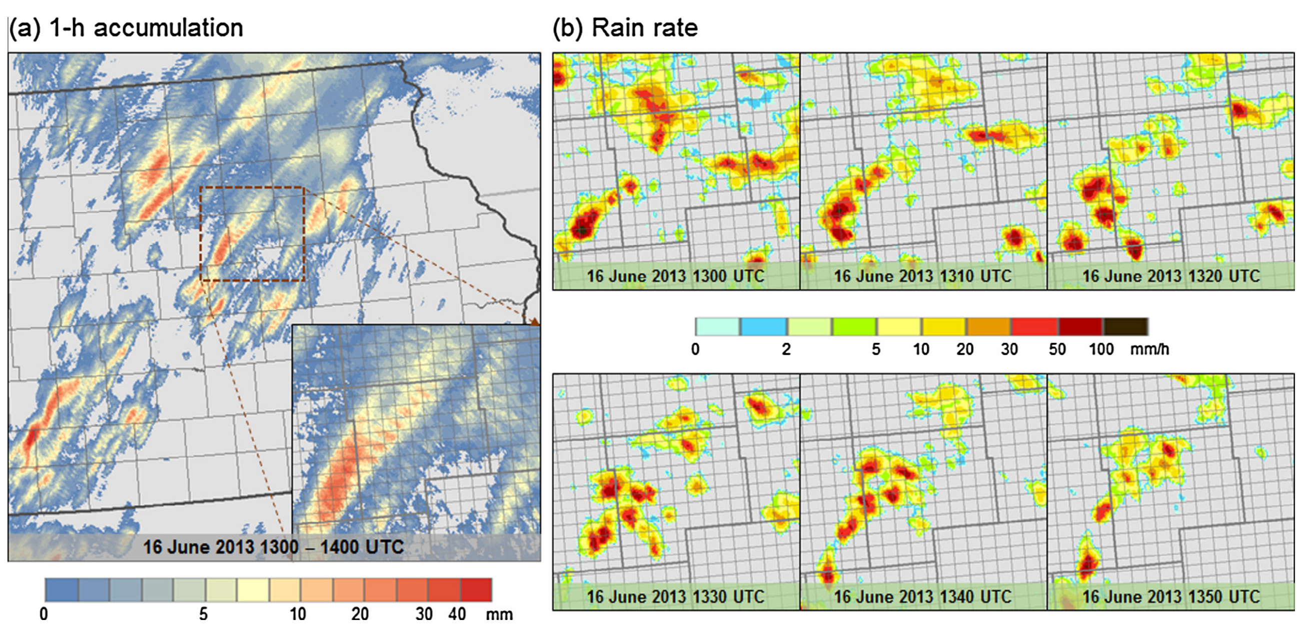

Fig. 2. Example maps of high resolution (0.5 km) rainfall (a) accumulation and (b) rate. The rain rate maps are illustrated for the inset area in (a). The 1-h accumulation map was created using thirteen 5-min rain rate products that were generated by the Iowa Flood Center. The accumulation map clearly shows spatially discontinuous rainfall patterns along the storm paths (e.g., southwest to northeast), which are caused by the periodic sampling of radar and rain storm movements in (b). The grid lines in the maps indicate approximately 5 km spacing.

is that radar-rainfall estimates are subjected to many sources of uncertainty, and it is therefore difficult to isolate the effect of advection and temporal sampling. These factors, combined with the sparseness of the rain gauge networks that are suitable for meaningful evaluation, make a quantitative demonstration challenging.

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