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EVALUATION OF NETWORKED BASED ATTENUATION CORRECTION IN CASA IP-1 TESTBED

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ABSTRACT

Monitoring of precipitation using higher frequency radar systems such as X-band is becoming popular. At X-band frequency, weather radar signals are attenuated along their paths due to precipitation. A network-based reflectivity retrieval technique has been developed for the Adaptive Sensing of the Atmosphere (CASA) system, which is a radar network that can observe a weather event simultaneously by multiple radars in different locations. In this paper the network based attenuation correction will be evaluated by CASA Integrated Project 1 (IP1) data during 2007-2009 field experiments. The results show that the networked based attenuation correction algorithm retrieves reflectivity properly.

Index Terms — *X band,* Network, Attenuation correction, CASA IP1

1. INTRODUCTION

The Engineering Research Center for CASA (CASA ERC) has been established to create the underlying scientific and engineering basis for a new paradigm of Distributed Collaborative Adaptive Sensing (DCAS) radars applied to hazardous localized weather detection, tracking, and predicting. DCAS is a new approach to radar sensing of the atmosphere being investigated to overcome the coverage limitation inherent in long-range radar networks. To be able to provide economically viable solutions to this approach, meteorological radar operation must change from the "preferred" S-band operation to higher frequencies so that physically smaller antennas can be deployed (McLaughlin et al.). However, at higher frequencies, the impact of attenuation due to precipitation needs to be resolved for successful implementation.

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Since Hitchfeld and Borden (1954) proposed the attenuation correction technique based on empirical relationship of reflectivity versus specific attenuation, many attenuation correction algorithms have been developed. For ground radars with polarimetric capability, a simple attenuation correction method using differential phase was discussed in Bringi et al. (1990). Subsequently, a constrained solution for path-integrated attenuation derived from differential propagation phase shift (ϕ_{dp}) was proposed (Testud et al. 2000). This algorithm is sensitive to the specific attenuation versus specific differential phase parameterization. To eliminate this problem, Bringi and Chandrasekar (2001) suggested a self-consistent algorithm combining differential phase shift and differential reflectivity constraint. In addition, Gorgucci et al. (2008) has developed a self consistent attenuation correction procedure. For networked radar systems, Chandrasekar and Lim (2008) proposed a methodology for reflectivity retrieval in a networked radar environment. A solution for the specific attenuation distribution can be provided by solving the integral equation for reflectivities from networked radars.

This paper presents the extensive evaluation of the network-based reflectivity retrieval technique using CASA IP1 data during 2007-2009 field experiments. The evaluation carried out in theoretical and experimental ways. Theoretical way is to compare retrieved results with theoretical relationship. This can provide fundamental validity for retrieval algorithm. Comparison with conventional attenuation correction method and observations of WSR-88D radars is for experimental evaluation. Comparison with WSR-88D observations is based on concept that intrinsic reflectivityies at S and X are similar. This way can validate the performance of the algorithm.

2. METHODOLOGY

Electromagnetic waves backscattered from a common volume in networked radar systems are attenuated differently along the different paths. The specific attenuation distribution can be retrieved by solving the integral equation for reflectivity and attenuation. The set of governing integral equations describing the backscatter and propagation of common resolution volume are solved simultaneously with constraints on total path attenuation. The intrinsic reflectivity at a common volume of the multiple radars can be obtained by a networked radar approach with a hypothesis that the intrinsic reflectivities at common volumes observed by each of the radars are the same. The optimal retrieved reflectivity at a common volume can be obtained by making an initial seed value of reflectivity and iteratively solving for it. The details are described in Chandrasekar and Lim (2008).

The first generation testbed of the CASA-IP1 is currently operational in Oklahoma. The CASA system is a radar network that can observe a weather event simultaneously by multiple radars in different locations. The IP1 network is composed of four X-band radars located over a grid off as 13.2, -13.8, 15.5, -15.5 km at East-West direction and 22.7, 5.2, -1.6, -22.7 km at North-South direction from the center of the network (Cyril (KCYR), Chickasha (KSAO), Lawton (KLWE) and Rush Springs (KRSP)), respectively. Figure 1 depicts the configuration of the CASA IP1 network.

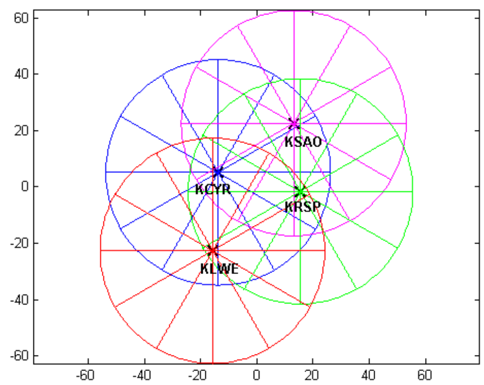

Figure 1. The configuration of CASA IP1 network.

3. EVALUATION

The network-based reflectivity retrieval technique has been evaluated extensively using CASA IP1 data during 2007-2009 field experiments. The retrieval results of the algorithm are evaluated by two ways. One way is to compare with theoretical relationship such as non-attenuated reflectivity (Z_h (dB)) versus specific differential phase (K_{dp} (deg/km)). This method can provide comparison validity by self consistency. The other way is comparison with conventional attenuation correction methods and against non-attenuated measurement. This method can provide external validity.

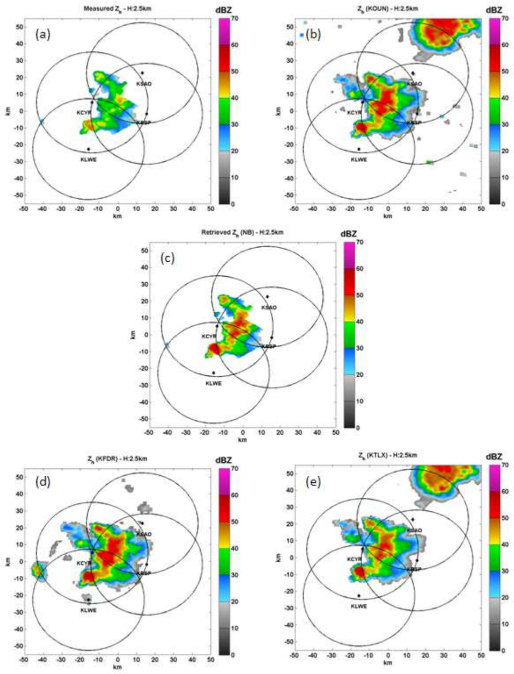

Figure 3. Evaluation of June 10 2007 case: Composite of (a) observed reflectivity by CASA IP1 radars (KCYR, KSAO, KLWE and KRSP), (b) reflectivity from KOUN radar, (c) retrieved reflectivity by network based reflectivity retrieval, (d) reflectivity from KFDR and (e) KTLX.

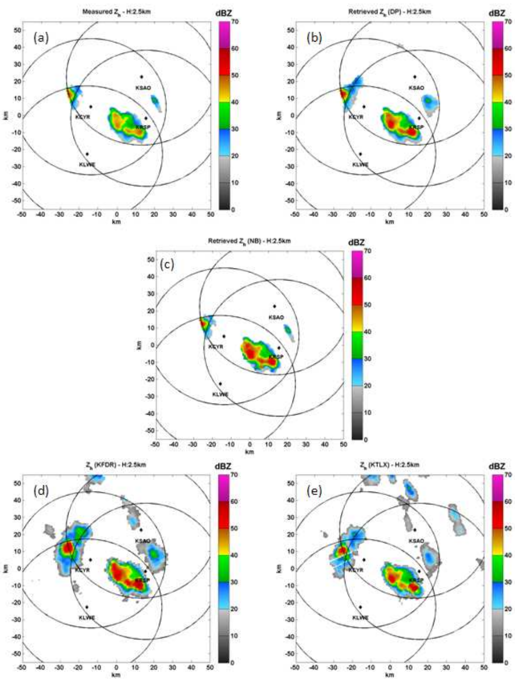

Figure 4. Evaluation of June 16 2008 case: Composite of (a) observed reflectivity, (b) retrieved reflectivity by conventional rain profiling algorithm, (c) retrieved reflectivity by network based reflectivity retrieval, (d) reflectivity from KFDR and (e) KTLX.

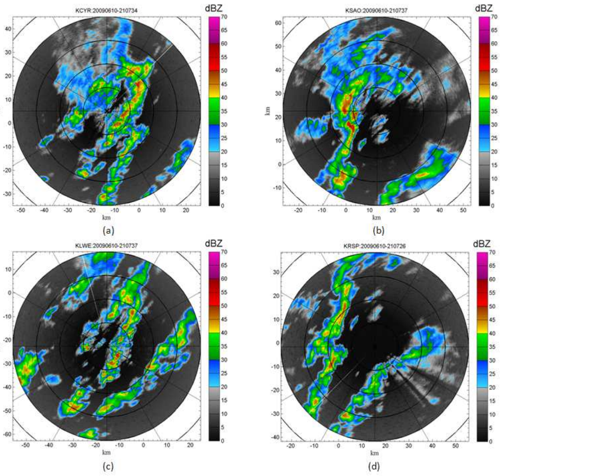

Figure 5. Observed reflectivities from CASA IP1 radars: (a) KCYR, (b) KSAO, (c) KLWE and (d) KRSP on June 10 2009.

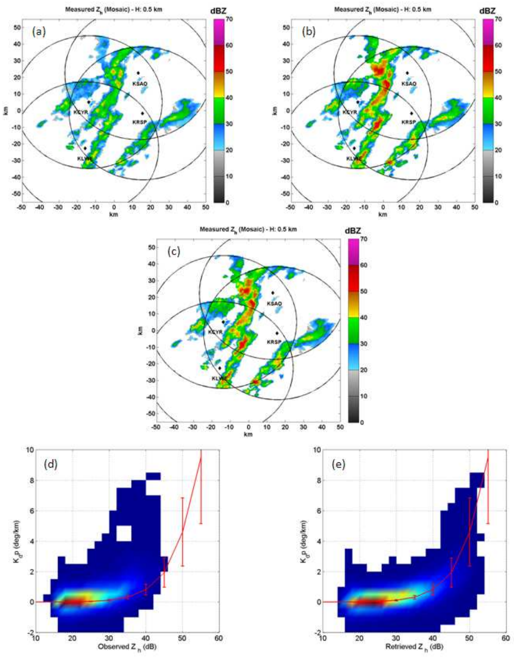

Figure 6. Evaluation of June 10 2009 case: Composite of (a) observed reflectivity, (b) retrieved reflectivity by conventional rain profiling algorithm, (c) retrieved reflectivity by network based reflectivity retrieval, scatter plot of (d) measured reflectivity (Z_h) versus specific differential phase (K_{dp}) and (e) retrieved reflectivity (Z_h) by network based retrieval algorithm versus specific differential phase (K_{dp}). Solid red line shows theoretical relationship between intrinsic Z_h and K_{dp}.

WSR-88D radars (KFDR, KTLX and KOUN) are located over a grid off as -80.5, 74.8 and 58.0 km at East-West direction and -51.3 56.4 and 45.5 km at6 North-South direction from the center of the CASA network respectively. In this paper results of reflectivity retrieval system have also been compared with the conventional rain profiling algorithm (Bringi and Chandrasekar 2001) operating in CASA IP1 systems. Based on internal and external evaluation, the network based retrieval approach can be validated effectively.

Evaluation has been carried out extensively with three years data collected from CASA IP1 systems. For brevity, five cases are showed here. The test data were collected on June 10 2007, June 16 2008, May 24 2009, June 2 2009 and June 10 2009. The events on June 10 2007, May 24 2009 and June 10 2009 were severe convective storms. Event of June 2 1009 is a moderate rain storm, where June 16 2008 was scattered shower event. Figure 3 shows comparison of retrieved reflectivity by network approach and reflectivity from WSR-88D radars (KOUN, KTLX, and KFDR) on June 10 2007, where the comparison results for June 16 2008 are shown in Figure 4. Evaluation results of June 10 2009 are shown in figure 5 and 6. Figure 6 shows the observed reflectivities from all four radars on June 10 2009.

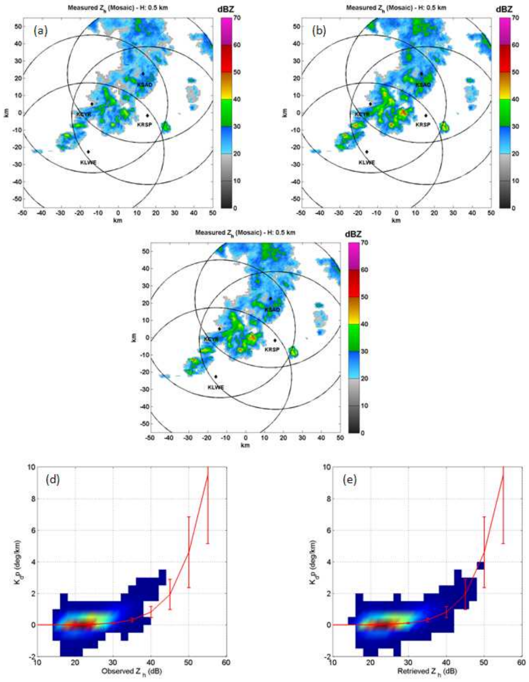

Figure 7. Evaluation of June 2 2009 case: Composite of (a) observed reflectivity, (b) retrieved reflectivity by conventional rain profiling algorithm, (c) retrieved reflectivity by network based reflectivity retrieval, scatter plot of (d) measured reflectivity (Z_h) versus specific differential phase (K_{dp}) and (e) retrieved reflectivity (Z_h) by network based retrieval algorithm versus specific differential phase (K_{dp}). Solid red line shows theoretical relationship between intrinsic Z_h and K_{dp}.

Figure 6 shows the internal and external evaluation results for June 10 2009 case. Figure 6(a) is the composite of observed reflectivity from all four radars. Figure 6(b) is the retrieved results by the conventional rain profiling algorithm currently operating on CASA IP1 systems, where as figure 6(c) shows the retrieved reflectivity by network based approach. Figure 6(d) is scatter plot of observed reflectivity and specific differential phase, where scatter plot of retrieved reflectivity and specific differential phase is shown in figure 6(e). Solid red line in Figure 6(d) and (e) shows the theoretical relationship between intrinsic Z_h and K_{dp}. Evaluation results for June 2 and May 24 2009 are shown in figure 7 and 8. From the results of extensive evaluation, we can see networked based reflectivity retrieval algorithm works reasonably. Comparison retrieved results by network approach with conventional attenuation correction and observations from WRS088D radars shows good agreement.

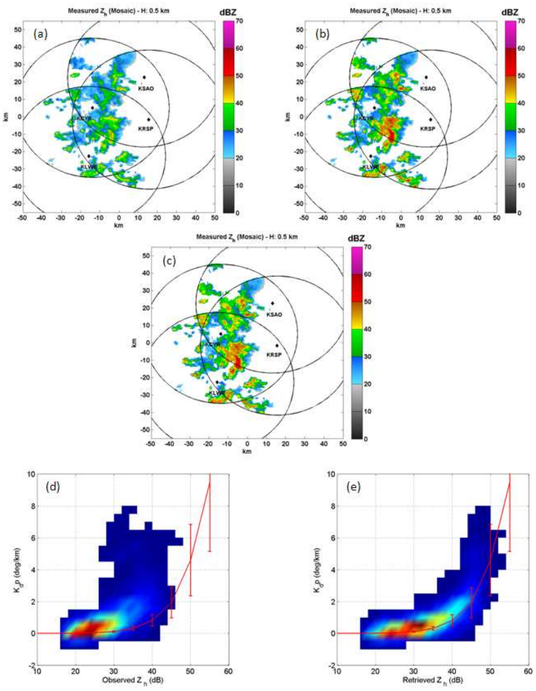

Figure 8. Evaluation of May 24 2009 case: Composite of (a) observed reflectivity, (b) retrieved reflectivity by conventional rain profiling algorithm, (c) retrieved reflectivity by network based reflectivity retrieval, scatter plot of (d) measured reflectivity (Z_h) versus specific differential phase (K_{dp}) and (e) retrieved reflectivity (Z_h) by network based retrieval algorithm versus specific differential phase (K_{dp}).

4. SUMMARY

The network-based retrieval algorithm has been evaluated extensively by comparing against WSR-88D observations during targets of opportunity as well as using self consistency for the CASA Integrated Project 1 (IP1) data during 2007-2009 field experiments. By comparing retrieved results with theoretical relationship, performance of network approach validated well as shown in Fig 3-8. The retrieval results by network approach show good agreement with results of conventional attenuation correction method and observation of WSR-88D radars. Based on the test results for three years data set, we can conclude that the network-based reflectivity retrieval algorithm performs well in a variety of environment. It is noted here that the network based retrieval does not use dual polarization observations.

ACKNOWLEDGEMENT

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