Simultaneous State Estimation and Attenuation for Thunderstorms with X-band Radar Data Using Ensemble Kalman Filter: Experiments with the CASA X-band Radar Network

Jing Cheng and Ming Xue
Center for Analysis and Prediction of Storms, School of Meteorology
University of Oklahoma

Abstract

To successfully use reflectivity data from X-band or other short-wavelength radars (e.g., typically airborne radars) for quantitative precipitation estimation and storm-scale data assimilation, attenuation correction is built into the data assimilation system by calculating the expected attenuation within the forward observation operators based on the estimated atmospheric state. Prior assumption about the types of hydrometeor species along the radar beams is not required in such a procedure, which allows us to take advantage of the knowledge about the hydrometeors obtained through data assimilation and state estimation. Xue et al. (2010) tested this methodology with simulated data from a single radar and for a supercell storm. Here we apply this approach into latest version of ARPSEnKF, and evaluate its effect under CASA IP1 radar network through OSSEs. Three types of squall lines (unicelluar, multicell, and a line of super cell) are generated as truth simulations.

Experiments	Obs. assimilated	Obs. error	Localization radius
vs15att	Z	2dB	4dx
vs15attvr	Z and Vr	2dB	4dx
obserr1	Z and Vr	1dB	4dx
obserr2	Z and Vr	4dB	4dx
loc1	Z	2dB	3dx
loc2	Z	2dB	5dx
loc3	Z	2dB	2dx

Table 1. Lists of Experiments for Unicellular case

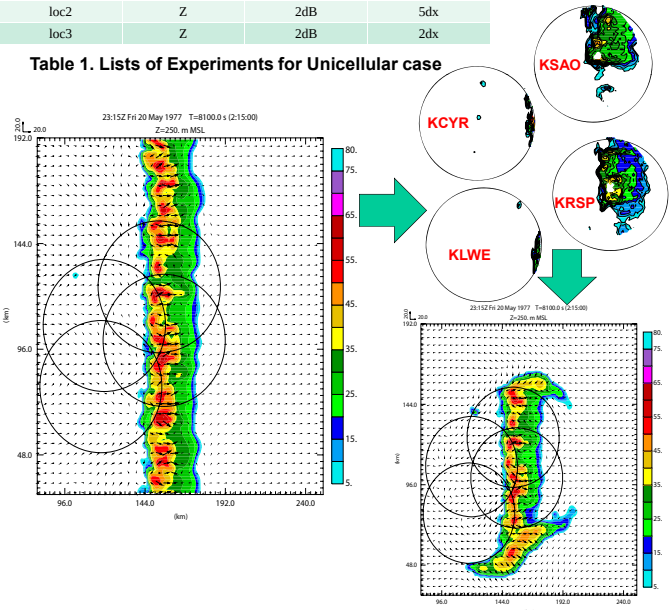

Figure 1. Truth simulation (left), simulated Z observations for each CASA radar (upper right), and ensemble mean analysis from experiments (lower right).

Research Objectives

- Propose an alternative approach to dealing with attenuation in short-wavelength radar reflectivity data, when they are used to initialize storm-scale numerical weather prediction (NWP)models.
- Evaluate its ability, and design an appropriate procedure of assimilating CASA radars data under different weather conditions to achieve optimal benefits.

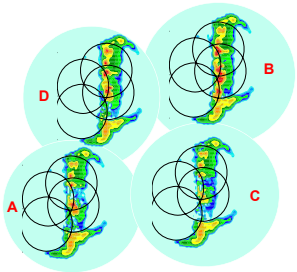

Figure 5. Ensemble mean analysis from experiments which analysis radar data in different sequence.
A: KSAO-KCYR-KRSP-KLWE
B: KLWE-KRSP-KCYR-KSAO
C: KSAO-KCYR-KLWE-KRSP
D: KSAO-KRSP-KCYR-KLWE

Future Work

- Evaluate the approach by adding model error into OSSEs.
- Test a variational framework for EnKF analysis which can handle localization in the grid point space. This is important for attenuated data whose observation operator is nonlocal.
- Apply the approach to real X-band observations collected in the CASA project, and compare the results against traditional attenuation correction methods.

Configurations

- The Advanced Regional Prediction System (ARPS) is used.
- Idealized squall lines of 22 May 1997 Delcity supercell with $\Delta x = \Delta y = 1.5$ km and $\Delta z = 500$m.

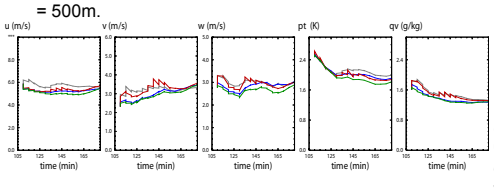

Figure 2. Ensemble mean analysis RMS errors for u, v, w, θ, qv, qc, qr, qi, qs and qh, for experiments vs15att(gray), vs15attvr(blue), obserr1(red), obserr2(green). Units are shown in the plots.

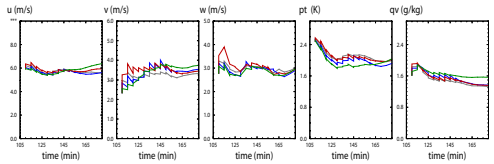

Figure 3. As Figure 2, but for experiments vs15att(gray), loc1(blue), loc2(red),loc3(green).

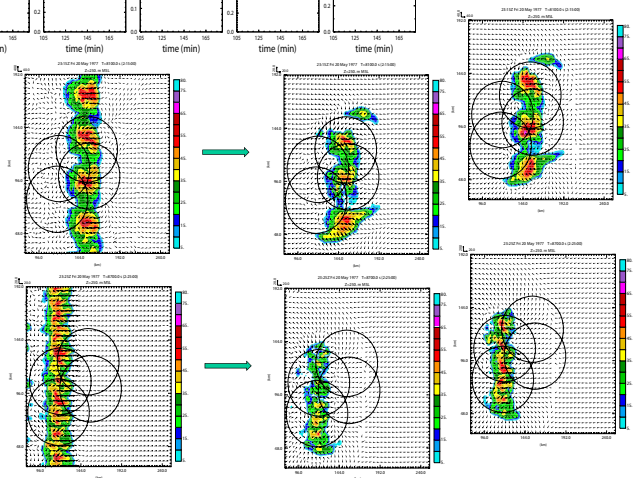

Figure 4. Truth simulation (left), ensemble mean analysis from fast moving strong shear squall-line (upper) and slow moving weak shear squall-line (lower) with different assimilation frequency(five mins middle, two mins right).

Progress and Results

- When we used to deal with radar data that attenuated seriously, discard radar data which reflectivity is below certain threshold (ex. 10dBz) is a prevalent choice to avoid effects of attenuated radar data during analysis. Compare to this method, the new approach can restore convective system as much as possible while suppressing spurious echoes. In the fully attenuated area, single radar couldn't rebuilt storm in limited cycles either, however in CASA radar network with help of other radar which detect the same storm in different angle, still the storm information could be captured and rebuilt partially.(Figure 1)
- The results suggest that regular observation error can effectively utilize attenuated radar data and assuming larger obs. error can improve the results while using this approach (Figure 2). And although in this whole path integration algorithm we want to reduce the effects of localization, 3Δgrid space is the minimum to use. Otherwise RMS error will be larger (Figure 3).
- Increasing data assimilate frequency can improve analysis results significantly, for which we can take benefit from CASA radar. (Figure 4)
- Under X-band network, each attenuated radar observation has larger difference for detecting same storm from different angle, which is not like S-band radar network. And since we are using ENSRF in all experiments which assimilate radar sequentially. How to set up radar assimilation sequence also matters the results.(Figure 5)