Response to Reviewer Comment #3

Thank you very much for your appreciation of our manuscript and giving valuable suggestions that have helped to improve the manuscript. Taking into account comments from all reviewers, we reorganized the sections. The following contains our detailed responses to your comments, with our responses in plain text given underneath your original comments in bold type.

Specific comments:

1. Page 4, lines 1-7. The first line of page 4 states, "Data were calibrated and processed according to several standard methods in the literature, . . ." The manuscripts needs to clarify what ARM data are used in this study. Specifically, were the data calibrated and processed by ARM or by the authors of this manuscript. Also, the manuscript should include the DOI numbers of the ARM datasets used in this study and whether or not the data processed by this research team are available for others to analyze. Line 7 on page 4 states that the radar data are mapped to a common Cartesian analysis domain. I thought ARM already produced a radial moments to Cartesian coordinate moments data product. The manuscript needs to clarify whether or not this common Cartesian data is the same or different than an ARM data product.

We have included additional information on the processing and datasets / availability. Radar reflectivity observed by CSAPR-I7 was corrected for attenuation in rain using the CSAPR-I7 specific differential phase (Kdp) measurements, as implemented using previously published methods. These include those as available also from ARM open-source python codes (Bringi and Chandrasekar, 2001; Giangrande et al., 2013b, 2014; Helmus and Collis, 2016). Because XSAPR reflectivity were significantly attenuated in rain (sometimes extinguished through heavier rain), for the XSAPRs, we only consider the mean Doppler velocity measurements in these retrievals (e.g., as mean Doppler velocity measurements are far less influenced by partial attenuation in rain). Aliased radial velocity measurements from all radars were corrected / dealiasied using the four-dimensional technique described in James and Houze (2001). We improved our description for this in section 2.1 of the revised manuscript.

In addition, we have added appropriate citations for the ARM datasets (Atmospheric Radiation Measurement (ARM) Climate Research Facility. 1996, 2011) to the text, and references including the DOI#s for those raw datasets. Nevertheless, processed radar datasets of this sort are generally unavailable to be placed immediately on the ARM archive. In part, this is because the accepted PI-products (processed) would typically not be released to that archive until those datasets are associated with a formal publication.

For this study, we mapped all scanning radar datasets (CSAPR, 3 XSAPRs, and NEXRAD KVNX radar) to the common Cartesian domain with 0.25-km horizontal and vertical grid spacings. This is different from the ARM Mapped Moments to a Cartesian Grid (MMCG) Value Added Product, which has a 240 km x 240 km domain with 1-km horizontal and 0.5-km vertical spacings. We described the domain size and spatial resolution settings and the interpolation method used in this study in section 2. Since this particular ARM product is not used (e.g., we start from the raw ARM datastreams), we did not see need to describe the differences between our gridding and those from the ARM Cartesian coordinate data products. However, we can understand if there is some confusion. Moreover, we need to differentiate these efforts since those MMCG products would not have the same detail/attention for velocity dealiasing or attenuation correction in rain as what was done for this study (both corrections must happen in radial coordinates prior to gridding). We do anticipate that future ARM radar products (CMAC-series) should have appropriate corrections for attenuation in rain and velocity dealiasing prior to gridding. Some of these features have already been made publically available for some transparent processing through ARM's open-source python radar processing toolkits, Py-ART. What those codes cannot replicate is any manual (investigator) quality control checks, filtering or similar that semi-automatic processing (no matter how good) can likely replicate (a subject that is still a problem for storm scale velocity dealiasing in particular for this community).

2. Page 4, lines 15 to 19. The manuscript should state the weights used in this study. As written, the manuscript describes that the weights are important, but not the actual weight values. If this work is to be repeatable by others, then the weights of the gridding should be published in this manuscript.

Weights calculated by Eq (1) were used to map the radar data to the Cartesian coordinate domain. Figure 3 in the revised manuscript shows nearest neighbor distance at each gird point and its weights. We also used the nearest neighbor weights as the observation constraint weights of the cost function in the 3DVAR retrieval (section 3.1).

3. Page 4, lines 1 to 19. The manuscript needs to describe in this section what radar observations are used in this manuscript. With the importance of preserving the phase and amplitude information of the input radar data (see line 19), the reader is led to believe that a phase measurement (e.g., Kdp) is used in this study. But in later pages, it appears that only reflectivity and radial velocity are used in this study.

As in previous responses and our revised manuscript, we used 4 radars from the ARM scanning precipitation radar network and one radar from the NEXRAD WSR-88D S-band radar network. The ARM radar network includes a 6.3-GHz C-band scanning ARM precipitation radar (CSAPR-I7) and three 9.4-GHz X-band scanning ARM precipitation radars (XSAPRs, named I4, I5, and I6) for the multi-Doppler radar wind retrieval.

As noted, in the revised manuscript, radar reflectivity values as observed by CSAPR-I7 are significantly attenuated in rain and are needing to be corrected for attenuation in rain using the CSAPR-I7 differential phase measurements. We have removed mention of 'KDP' to avoid additional confusion. While basic procedures are part of dual-pol XSAPR reflectivity processing, these measurements were more significantly attenuated in rain, thus we only rely on the mean Doppler velocity measurements from the XSAPR for these retrievals (e.g., ultimately XSAPR correction is a nonfactor in our results). Similarly, NEXRAD radar observations are from the dual-polarization NEXRAD (KVNX was upgraded prior to

MC3E in 2011) may also be corrected for attenuation using differential phase measurements. In an equal, but opposite manner, it should be noted that performing the correction methodologies for attenuation in rain at S-band are arguably also less important to our findings (e.g., S-band being relatively unattenuated wavelength). Aliased radial velocity measurements from all radars were corrected using the four-dimensional technique described in James and Houze (2001). We described this in section 2 in the revised manuscript.

The ARM zenith-pointing radar wind profilers at two locations, UAZR-C1 and UAZR-I9, were used to evaluate the multi-Doppler wind retrieval. These locations are shown in Fig. 1.

4. Page 5, line 14. This reviewer noticed the phrase "surface impermeability". That is a fancy way of saying "surface boundary condition".

"Surface impermeability" was introduced by Scialom and Lemaître (1990) as a vertical velocity boundary condition at the ground level. This concept has been used in the 3DVAR analysis by several papers, and this phrase has been conventionally used (e.g., Shapiro and Mewes 1999). Therefore we decided to use this phrase in this paper and added the following sentences to section 3.3: "This study imposes surface impermeability (Scialom and Lemaître 1990) as a vertical velocity boundary condition at the ground level.".

5. Page 5, lines 13-22. I found this section hard to read because the cost function terms are not defined. The manuscript needs to define the cost functions of Jo, Jc, Jp, Jb, and Js. As written, these terms are not introduced until subsequent section headings.

Thank you for pointing out. We defined the physical constraints of radial velocity observations (J_o), anelastic mass continuity (J_c), surface impermeability (J_p), background wind field, (J_b), and spatial smoothness (J_s) in the beginning of section 3.

6. Page 8, line 25 and onwards. The variable names for the weights are different in the text and in the figures. These different variable names is very confusing for the reader and the manuscript needs to be corrected.

See our response to comment # 5.

7. Table 2. I found the entries for pulse width and range resolution to be confusing and possibly redundant. The entry for the UAZR range resolution is either 200 meters or 120 meters, not both, please correct or clarify.

The radar wind profilers operate using two alternating modes, a long pulse mode (200 m gate spacing, to ~15 km, ~20 m/s Nyquist) and a short pulse mode (120 m, to ~9 km, ~14 m/s Nyquist). The reviewer is correct that all that really matters is that we have a single merged profiler dataset (at the 200 m resolution) that combines those two modes (a staggered PRT approach also assists in dealiasing of profiler velocities), e.g., as in Tridon et al. [2013], etc. We added parameter settings of the two modes to Table 2.