Manuscript amt-2015-171 – Reply to Reviewer # 4

The Authors are grateful to the Reviewer for the time spent analyzing the manuscript, and for the constructive comments which helped us to improve the manuscript quality.
We believe to have addressed all the technical remarks.
In the following paragraphs, we reply item-by-item to the Reviewer comments, which are enumerated and copied in blue color.

General Comments

1. The authors correct reflectivity and differential reflectivity for attenuation and differential attenuation in rain. How the attenuation effects by wet hail remain to be largely unknown and not accounted for. Did you make any attempt to account for hail attenuation? Or you just neglected this additional attenuation? In any case you have to justify your handling of hail attenuation and differential attenuation.

   REPLY. A specific procedure for compensating additional wet hail attenuation has not been used. In fact, quantification of wet hail attenuation can be very tricky and uncertain depending on many factors, such as the particle size and shape, as well as on the water coat thickness, which can modify the shape and fall orientation (Rasmussen and Heymsfield, 1987).
   To our knowledge, stable approaches that can "operationally" deal with such effect at X-band are not yet available, although research on this topic is ongoing.
   Tabary et al (2009) who analyzed 2 years of data were able to apply the so-called "Smyth and Illingworth constraint" (Smyth and Illingworth, 1998), which uses the constraint that the value of the differential reflectivity Z_{DR} on the stratiform tail of the storm should be low, only in the 20 % of the cases. Ryzhkov et al. (2013), proposed a methodology to compensate hail attenuation at S-band starting by the well-known ZPHI method. However, they concluded that "Attenuation/differential attenuation correction in hail at C and X bands can be performed using the approach that is applied for S band in this study. Testing such an approach at shorter wavelengths is a subject for future investigation. The proposed method for attenuation correction in hail implies the estimation of the average magnitude of specific attenuation Ah within the hail core, which is sensitive to maximal hail size and can be potentially utilized in HSDA. This hypothesis requires further exploration."
   ACTION: The revised manuscript will include a discussion on this topic.

2. It appears that the authors use fixed values of the coefficients in the attenuation KDP and differential attenuation – KDP relations (0.29 km/dB and 0.048 km/dB, correspondingly). Recent studies (see DOI: 10.1175/JTECH-D-13-00231.1) where such coefficients were derived from dual-wavelength measurements without any theoretical assumptions indicated a fair amount of variability in these coefficients from one event to another. How the natural variability in these coefficients can affect the results of your study? Please include discussion on this topic.

   REPLY. The variability of the coefficients relating K_{DP} to attenuation and differential attenuation is known to affect the correction of Z and Z_{DR}. Actually, the coefficients of the K_{DP} - based algorithms for specific attenuation and differential attenuation estimation, derived from 3 years of DSDs observations, present Normalized Standard Error of .65 and .75, respectively, that justifies the fact that optimal coefficient may vary among different events.

Carey et al., 2000 were among the first to propose potential optimization approaches to mitigate this problem. Bringi et al., (2001) proposed a self-consistency based methodology relying on the comparison between the measured differential phase and the one retrieved by inverting the estimated path integrated attenuation. This approach, however, might be sensitive to non-uniform beam filling along the path, residual clutter, backscattering differential phase. Vulpiani et al., (2008), proposed an optimization technique based on preliminary model-based rain type classification. This approach is sensitive to the adopted scattering model and microphysical parameterization.
Such procedures might not be robust enough to be suitable for operational implementation.
ACTION: The issue will be discussed and a reference to the paper suggested by the reviewer will be inserted in the revised manuscript in order to point out possible differences between events of the parameterizations of specific attenuation and differential attenuation based on K_{DP}.

3. In Figs. 4 and 11. The authors present quasi-vertical profiles of observed radar variables. Even though the study is about intense precipitation, these vertical profile are shown for times when precipitation was very weak (reflectivity < 20 dBZ near the ground and the corresponding ZDR is very small). It is not very informative. Can you show the vertical profile data for heavier precipitation?

   REPLY. The considered radar scan over 13 tilts, the last one is run at the vertical incidence (90 deg), with the aim to estimate the differential reflectivity calibration bias (resorting to the medium scattering property) and the vertical profile of precipitation, including the zero degree isothermal height. This information is used to testify that the Z_{DR} was miscalibrated by less than -0.1 dB, that is within the typical tolerance (0.2 dB).
   These information can be retrieved if rain and wet radome attenuation can be neglected, i.e., when the precipitation over the radar is weak.
   ACTION: The point will be clarified in the revised paper.

4. ZDR in the vertical profile (Fig. 4) is negative. How it could be? Especially it is very strange for the rain layer.

   REPLY. As specified in the previous reply, Z_{DR} showed a slightly negative bias. be have kept it, Being within the typically accepted tolerance.

5. In presence of hail, it is generally unknown what fraction of the observed backscatter from a particular radar resolution volume comes from hail. The reflectivity due to rain in a hail-rain mixture will always be smaller than total reflectivity. In this case you will be overestimating rain rate when you use the Z-R relation and the corresponding weights from Eq. (3) are less than How do you handle this problem?

   REPLY. The Reviewer is right, indeed to overcome this problem Z has been capped to 55 dBZ before estimating the rain rate.
   ACTION: We will mention this point.

Specific comments

1. How many gauges overall were used to get statistics in shown in Tables 1 and 2? What type of gauges they were?

   REPLY. The number of rain gauges available in Sicily is about 200. We used all the available

rain gauges located within the radar coverage (76), e.g. 55 of them registered precipitation (>0.2 mm) on 21st August 2013 whereas only 31 on the 21st of February 2013, the storm having affected mostly the coastline. The instruments are tipping bucket rain gauges**.**
ACTION: this information will be added to the revised manuscript.

2. Terminology: I suggest that the authors when talking about attenuation affecting ZDR specify this as differential attention (not just attention as some parts of the text refer to).

   REPLY. Right.
   ACTION: The paper will be modified accordingly.

3. Page 7203, line 23: Is it the same radar or the same type of radar?

   REPLY. Right, it is the same type of radar.
   ACTION: The paper will be modified accordingly.

4. Page 7204, line 10: Actually al WSR-88D units are being operated in the dual-pol mode (correct the reference to these units as single polarization units).

   REPLY. Agreed
   ACTION: The sentence "is currently used by …." will be modified into "it has been used by …."

5. Provide units for values shown in Tables 1 and 2.

   REPLY. Agreed
   ACTION: The paper will be modified accordingly.

6. For the radar reflectivity you use interchangeably Z and Z_H. Please change it everywhere to Z_H. 7.

   REPLY. Agreed.
   ACTION: The paper will be modified accordingly.

7. Fig. 4: at what elevation angle were those azimuth-average vertical profiles derived?

   REPLY. As specified in reply # 3, it is the vertical incidence scan (90 deg)

8. Please define Vertical maximum Intensity (VMI). Are values in in Fig. 5 collected at different elevation angle or at a constant elevation angle?

   REPLY. The Vertical Maximum Intensity (VMI) is a map of maximum intensity (reflectivity) in the vertical (Fabry 2015), widely used for operational monitoring. Starting from the volume of reflectivity in polar coordinates, the VMI is a 2-D polar image obtained by looking for the maximum reflectivity with respect to the antenna elevation angle.
   ACTION: it will be clarified in the revised manuscript.

9. Are Z_H and Z_DR values shown in Figs. 4, 5, 6 corrected for attenuation?

REPLY. The reflectivity and differential reflectivity shown in Figure 4 are not corrected for attenuation. As clarified previously, the data are collected at vertical incidence, the aim of the figure is to show the Z_{DR} miscalibration. Whereas Figures 5 and 6 shows attenuation-corrected Z and Z_{DR}
ACTION: These points will be clarified.

Typing errors

1. There is a typo in line 18 (page 7208): I believe it is gamma_DP=0.048 not gamma_H=0.048. Also here provide units of the gamma coefficients

REPLY. Agreed.
ACTION: It will be corrected.

References

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