Authors Comment (AC)
On the Referee Comments (RC) #2 C5964

We thank the Anonymous Referee #2 for the thoughtful comments and constructive suggestions, which we will fully take into consideration in the revised manuscript. Item-by-item replies are inserted in blue, whereas the Referee comments are in black.

1) There should be a better appreciation of what the 2a25 algorithm does and does not do. It does not do rain detection or clutter detection/suppression. These are tasks done in the level 1 algorithm. As such, the question as to whether the v6/v7 version of 2a25 improves detection or clutter suppression is not a valid question. Even if the rain/surface clutter algorithms were changed in going from v6 to v7, 2a25 should not be evaluated in these terms since it's not the right place to look. Moreover, the best retrieval algorithm in the world will not improve the rain detection capability of the radar. It might be possible to increase the detection capability (though, with a probable increase in the false alarm rate) but as said above, this is not the responsibility of 2a25.

The Referee is correct in stating the rain detection and surface clutter discrimination are processed in the level 1 algorithm, for example, products 1B21 and 1C21, which feed in to the algorithm(s) used for generating the Level 2 products. For example, the near-surface rain rate from 2A25 is retrieved at the lowest point in the clutter free ranges, which are identified based on the output of 1C21 to separate rain echo free from the surface clutter. Moreover, the improvement of the clutter routine module in the PR 1B21 algorithm is apparent in the differences between V6 and V7. Therefore, the higher level product 2A25 can serve as a fair indicator of effective rainfall detectability of TRMM. Results from our analysis show no significant improvement of rainfall detection from V7 to V6 in complex terrain (see P. 11149, line 2-5), which is consistent with the conclusions drawn from Kirstetter et al. (2013).

2) The clutter detection/correction problem over mountains and hills is especially difficult: imagine trying to fit a 5 km pancake-shaped volume at different incidence angles into a valley without touching any of the surrounding hills. In many instances, what is thought to be rain return is probably surface clutter. I think that explains why the authors see cases of large overestimates of rain in the valleys. I do agree that with a higher resolution more accurate digital elevation map the clutter detection problem can be improved.

The Referee's point is well taken. One of the objectives of this work was to take advantage of multiple sources of concurrent and co-located observations to investigate in detail the conditions under which different types of error were identified that should be helpful to identify opportunities for algorithm improvements in regions of complex terrain although the challenges are complex, particularly at the current spatial resolution. Specifically in the case of surface contamination, special precaution should be taken when strong echoes are observed near the surface, which might be caused by surface clutter and should be excluded from rain analysis. In this study, the vertical profiles were carefully examined for each error class (see Section 3.3). The two severe cold season overestimation cases discussed in Section 4.2 are analyzed combining with surface radar, raingauges and weather reports. The ground-based observations suggest that large overestimations can be mainly attributed to the mixed-phase precipitation that cannot be estimated by the convective Z-R relationship in the algorithm.

3) I have difficulty interpreting the data in Table 3 which gives rain detection statistics between the gauge network and the TRMM PR. The PR overflies the site probably within a 10-20 second period so the different averaging times must apply to the different gauge averages. Is this correct? Why are these long averaging times (up to 1 hour) considered when the PR overpass is basically instantaneous? Since the site has been operational for 5 years, it might be worth looking for CloudSat overpasses. Even though these will be rare because of the narrow swath of CloudSat, since it has a much better resolution and higher detection capability, such comparisons could be informative.

First, we address the difference between the duration of the overpass and the time-scales of integration of gauge rainfall in Table 3. The various time-scales are used to estimate rainfall rate at the raingauges. Matching between point-scale raingauge measurements and TRMM PR estimates at pixel scale introduces space-time uncertainties due to differences in the spatial scale of measurement, and thus the measurement control-volume, and storm dynamics (i.e. the control-volume over which the measurement is averaged changes in time and moves with respect to the gauge locations), generally referred to as representativeness error (i.e. Porcù et al., 2014). These differences depend on the time-scale of the measurement proper for different types of raingauges as explained in the manuscript, the geometry of the overpass, and the satellite estimates correspond to a cloud volume-averaged rainfall rate that is highly dependent on the precipitation system, cloud physics and morphology, and associated rainfall (e.g. Pratt and Barros, 2010; Habib and Krajewski, 2011). Related detailed discussion can found in the replies to the first and second items in Authors Comment (C5384). The overcautious inclusion of the longer averaging times (1 hour) is due to the coarse resolution of the tipping-bucket gauges that were installed in the most remote western ridges in the Great Smokies National Park.

Second, we appreciate the suggestion to conduct a comparison with CloudSat. Indeed, a multi-year climatology study for fog and low level clouds over the Southern Appalachian Mountains was conducted by the authors using 8-years of the satellite-based observations (CALIPSO and CloudSat) and ground-based observations from ceilometers. As the Referee pointed out, the narrow swath and sparse sampling of CloudSat did not provide sufficient samples for statistical analysis in a small region like the Southern Appalachians. During 2006-2014, there are only 140 daytime overpasses over the raingauge network, and no nighttime data are collected after 2011 October due to battery anomalies in the satellite. Although the number of overpasses is limited, the joint analysis of the CloudSat and CALIPSO are very informative to fill in gaps and provide a more comprehensive description of the atmosphere for specific dates when other concurrent observations are available. The results were presented at the Fall meeting of the AGU in December (Duan and Barros, 2014), and a comprehensive manuscript is currently in preparation.

References

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