General comment:

We would like to thank all three reviewers for their vey insightful comments. This study has been a humbling experience for the first author who has dedicated several years working on extracting scientific value out of the ARM facility radars and other sensors. A great challenge was to consolidate the differences between the ARM radars and generalized enough an algorithm initially developed by Alain Protat to work on a much larger dataset.

A project website has been developed and gives a graphical overview of the calibration procedure as applied to each site and radar system described in the manuscript. The web site is now available to the ARM radar user community. We hope to continue updating the material on the web site as the ARM program conducts additional field deployments. We also plan to expand our analysis to the European radar network.

http://doppler.somas.stonybrook.edu/CloudSat_GlobalCalibrator/index.html

Anonymous Referee #1

Received and published: 10 April 2019 Review of the article titled "Calibration of the 2007-2017 record of ARM cloud radar observations using CloudSat" by Kollias and coauthors for publication in AMT.

The authors have compared the reflectivity from vertically pointing Doppler cloud radars at the ARM sites to the reflectivity from radar onboard polar orbiting satellite. The goal of this study is to characterize the performance of the ground-based radars, as the spaceborne radar is well-calibrated. They find significant calibration offset for the ground-based radars throughout the 10-year period, and inherent inconsistencies between the different modes of them. The technique is already well-established and used here in a relatively straightforward manner. The article is overall okay but needs several small tweaks in writing. Due the number of small corrections listed below; I recommend this article for major revisions.

Major Suggestions:

1) As the authors have already made CFAD of all the ARM radars, it will be relatively straightforward for them to calculate the minimum detectable signal (MDS) for them. You can just pick up the bottom 5% of reflectivity at 1 km and make its average. This will greatly assist the scientific user community, as it is unclear how sensitive are the ARM radars and if their sensitivity has changed through years. You already have the data for calculating this and hence will be a worthy and useful effort. If you do this, then you can add this as another column in Table 1. Thanks.

We would like to thank the reviewer for his comment. The detail tables with the calibration offsets, the RMSE and the number of samples have been provided to the ARM infrastructure. This study is not an official reference document for the ARM facility and the author team is not representing ARM in any capacity. Our understanding is that the ARM facility will consider our findings and decide a path forward on how to report them to the user community. This includes the requested

minimum detectable signal information that as the reviewer correctly suggests can be relatively easy released by ARM.

2) Please add one more column to Table 1 and report the average and standard deviation of the calibration offset for each radar. This table will be very useful for users who'd like to use your calibration offsets in their research. Please add the different modes of KAZR and MMCR in the rows. I understand that this will be an average through many years, but still worthy of reporting. Thanks.

If it fair to state that a considerable amount of work and analysis was performed to complete this long-term ARM – CloudSat calibration. As part of the manuscript, we are also releasing a web site that provide graphics and animations for all the ARM sites and radar systems compared to CloudSat. We hope that the reviewer and the larger user community will find the material on the web site useful.

http://doppler.somas.stonybrook.edu/CloudSat_GlobalCalibrator/index.html

3) The article ends abruptly, and you only provide a brief summary without discussing the implications of your results. It will be good if you can devote one paragraph each on the following two things i) the impact of calibration offset on the regular data products produced by the ARM program. I did a quick search and the radar reflectivity is used for doing microphysical retrievals like MicroBase and cloud drop concentrations. Please discuss how a calibration offset might affect these data-products. ii) The lead author has significant expertise in retrieving vertical air motion and microphysical properties from ground-based radars. A quick search made me realize that scientists have also used radar reflectivity in those studies in addition to using mean Doppler. It will be good if you can elaborate on how your results will impact the results previous studies by you and from Giangrande, Verlinde, Luke, Shupe, Dong, Chiu etc. So please add two separate paragraphs at the end and rename the section as "Summary and Discussion".

The reviewer is correct, the summary does ends abruptly. The impact of the calibration offsets reported here is not negligible and as the reviewer suggested, will affect any retrievals and/or data product that depends on calibrated radar reflectivity values. Here is the text added in the revised manuscript: "In most cases, the observed calibration offsets exceeded this uncertainty value suggesting that the ARM profiling radar record contains considerable calibration biases. The reported calibration biases are expected to have a large impact on routine ARM microphysical data products such as the Continuous Baseline Microphysical Retrieval (MICROBASE) value-added product [Zhao et al., 2012]. In addition, cloud retrieval techniques and associated products are impacted by the reported calibration offsets ([Shupe et al., 2015]; [Dong et al., 2014]). For reference, a 3-dB calibration offset is equivalent to a factor of 2 bias in hydrometeor content or number concentration retrievals. The estimated calibration offsets, the RSME's and the number of samples as a function of time for each radar system evaluated here have been provided to the ARM facility. The ARM facility is currently considering reprocessing of the ARM radar record with these new calibration offsets."

Minor Issues:

It is unclear to me if the authors are referring to the funding agency ARM or their observatories through the user facility. I recommend using the ARM Climate User Facility throughout the article. Thanks.

The reviewer is correct. ARM has not been a program since it was designated a user facility. Thus, we use "ARM facility" throughout the manuscript.

Page-1, Line 16: Add "collectively" before "Over". Thanks.

The manuscript is revised according to your suggestion. Thank you.

Page-1, Line 12: Add :1990s

The manuscript is revised according to your suggestion. Thank you.

Page-1, Line 15: the sentence doesn't read well, please rephrase.

The sentence is revised as follows: Here, a well-characterized spaceborne 94-GHz cloud profiling radar (CloudSat) is used to characterize the calibration of the ARM cloud radars. The calibration extends from 2007 to 2017 and includes both fixed and mobile deployments. Thank you.

Page 2, Line 8: "Surprise" not "surprised".

The manuscript is revised according to your suggestion. Thank you.

Page 3: Add outline of the paper before the section 2.

The manuscript is revised according to your suggestion. Thank you. Here is the revised last paragraph of the introduction:

"In section 2, the ARM facility cloud radars are presented and the Protat et al. [2011] methodology is revised and improved. Section 3 presents the results from the application of the calibration procedure to almost the entire record of ARM profiling cloud radar observations at the fixed and mobile sites from 2007 to the end of 2017 (at total of 43.5 years of radar observations). Finally, section 4 presents a summary on our finding and their implications. The application of the technique is such diverse set of radar systems and locations is expected to demonstrate the applicability of this approach to existing profiling radar networks such as the ARM facility and the future European research infrastructure network for the observations of Aerosol, Clouds and Trace gases (ACTRIS)."

Page 3, Line 19: "At couple of sites".

The manuscript is revised according to your suggestion. Thank you.

Page 4, line 1-2: Please rephrase and remove “us”.

The phrase is removed since it is basically a repetition of what is already mentioned in the previous paragraph. Thank you.

Page 4, Line 15: “Computed” and not “computer”.

The manuscript is revised according to your suggestion. Thank you.

Page 5 Line 10 and Page 7 line 13: It is unclear which numbers to believe.

The correct range is 200 to 300 km. We corrected the inconsistency between the numbers reported in page 5 and page 7 regarding the maximum distance of CloudSat observations used in the calibration. Thank you.

Page 5-6: It will be good if you mention the equation used for doing gaseous correction in CloudSat. Thanks.

The gaseous attenuation correction in the operational CloudSat products (R04/R05) is based on the Millimeter-wave Propagation Model (MPM) of Liebe 1989

H. J. Liebe, “MPM—An atmospheric millimeter-wave propagation model,” Int. J. Infrared Millim. Waves, vol. 10, no. 6, pp. 631–650, Jun. 1989

This information was added in the revised manuscript. Thank you.

Page 8 Line 15: “were” not “where”.

The manuscript is revised according to your suggestion. Thank you.

Page 10 Line 15: you mean “observatory” and not “laboratory”?

The manuscript is revised according to your suggestion. Thank you.

Page 11 Line 20: there is a typo, it should be 616 samples according to Page 7 line 32. Thanks.

The reviewer is correct. In the summary, we refer to the total number of 6-months ARM-CloudSat comparisons. A phrase was added to clarify the number of cases we were able to estimate a calibration coefficient. The revised manuscript reads as follows: “A total of 653 ARM – CloudSat comparisons are performed using a running 6-month time window. Acceptable calibration coefficients are estimated in 616 of the cases, a 94.3% success rate”. Thank you.