Reply to Referee 3

We do appreciate the reviewer provide so much important comments help us improving our manuscript. We'd like to address these comments as following.

1.) First of all, an important comment the proposed methodology, which uses the lowest unblocked scanning tilt, as stated by the authors at page 2 (Line 55). In my opinion, the authors should add a discussion about the weakness of such approach, considering, for example, the scenario in which it is applied in a complex-orography area. In such a case, the strategy may be not suitable, because the radar signal at lowest tilt may be totally or partially obstructed by the surrounding topography in some sectors. A possible solution to overcome this issue may be using the lower "free" available scanning elevation but this choice can generate inconsistencies and biases. For example, in some sectors of radar coverage, the algorithm may receive as input the reflectivity data collected at 1° elevation, in others the measurements sampled at 4° antenna elevation angle. The information provided by data sampled at 1° and 4° antenna elevation angle can be very different, depending on the precipitation type event that is taking place.

Response: Thank you for the reviewer pointing this out. First, we totally agree with the reviewer that a discussion about the weakness of the proposed approach is necessary, which can guide readers to evaluate and implement this approach. We added following discussion in the revised manuscript:

1.) **Line 56**: Different from some existing classification techniques that require whole volume scan of radar data, this new approach uses the lowest unblocked tilt data in the separation. If the lowest tilt is partially or completely blocked, then next adjacent unblocked tilt is used instead.
2.) **Line 336**: Limitations of proposed approach are also included in the discussion section as: First, this approach is developed for fast scanning and fast update purpose, therefore, data from the lowest unblocked tilt is used as the input. However, if the radar is located in a complex orography area, radar beam could be partially or completely blocked at some regions. A possible solution for such scenario is using a hybrid scan data from different scanning tilts as the input. Radar scanning tilts used in the hybrid scanning are determined by the radar scanning geometry**.** Given the factor that precipitation's microphysics (such as drop size distribution) from different altitudes may be significantly different, therefore, the performance of proposed approach may worse than expected.

Secondly, the data from 1.4° elevation angle is used in the current work. Following figures show the scanning geometry of RCMK, and this figure was also added in the manuscript as the reviewer suggested. From this figure, we can find that the data from 0.5° is severely blocked by the central mountain range. Therefore, data from 1.4° elevation angle (treated as lowest unblocked data) is used in the current work.

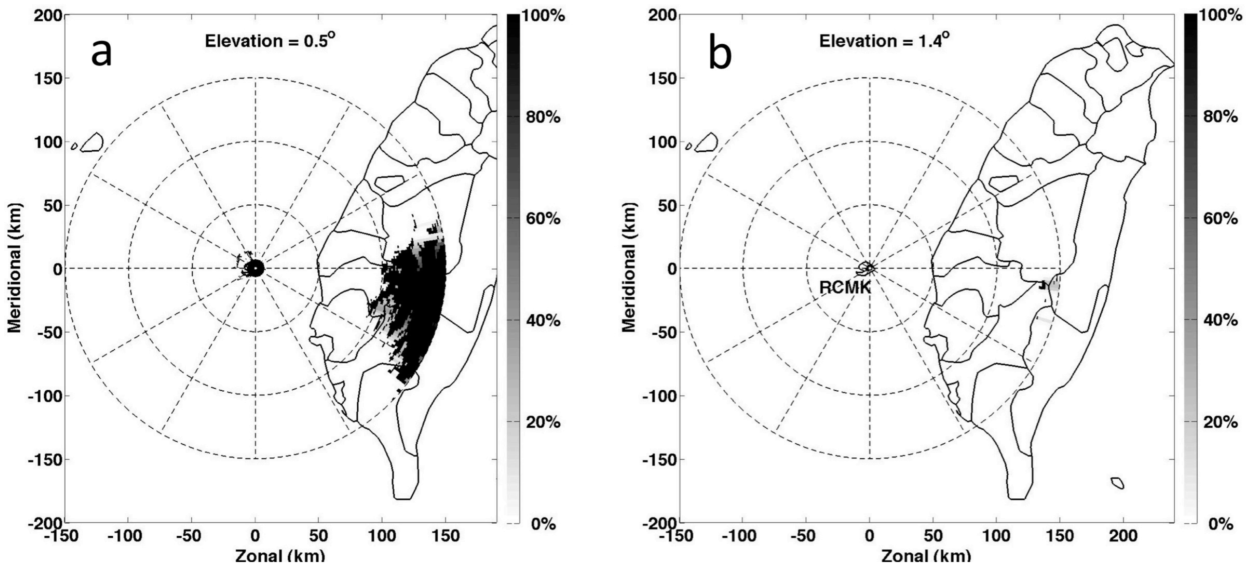

Figure 1. Blockage maps of RCMK from the first 2 elevation angles (0.5° and 1.4°). The grey scale indicates the blockage percentages.

2.) In Section 2, I suggest to add a figure showing the scanning geometry of the C-band polarimetric radars involved in this study. Please indicate the elevations angles used to develop the SVM method. Moreover, it is not clear if the authors used also the measurements provided by S-band single-polarization systems operating in the area of Taiwan.

Response: Following the reviewer's suggestion, a figure of the scanning geometry of RCMK is added in the revised manuscript. The data from 1.4° elevation angle (the lowest unblocked tilt) is used in the algorithm development. We included this clarification in the revised manuscript. The S-band single-polarization radar data is not used in the SVM approach. We clarify this too in the revised manuscript.

3.) In Section 2, the authors describe the variables used as input to the SVM method. They discuss about quality control of reflectivity measurements, focusing only on a specific issue, the attenuation along the path. I suggest to extend this discussion to other radar impairments that may have a strong impact on the performance of the proposed methods, such as the ground clutter (which strongly affects the radar measurements quality at lowest tilt) and the reflectivity vertical profile. In this respect, a detailed discussion should be provided about the bright band, which is a typical signature of stratiform precipitation events.

Response: Following the reviewer's suggestion, issues about ground clutter and VPR are discussed in the revised manuscript. The discussion about bright band is also included as suggested.

Line 98: Other quality control issues, including calibration, reflectivity vertical profile, and ground clutter removal, were also considered in this work. Since this radar is used in the real-time quantitative precipitation estimation, the biases of Z and Z_{DR} should be within 1 dBZ and 0.1 dB, respectively. The data quality of RCMK was examined through validating the QPE performance in different works (e.g., Wang et al., 2013, 2014). Therefore, the calibration bias of RCMK should be within a reasonable range. A vertical profile of reflectivity (VPR) correction is generally needed on the reflectivity field to reduce the measurement biases because of the melting layer (Zhang et al., 2011). Given the fact that 1.4° elevation angle is used within the maximum range of 150 km, and the melting layer is usually around 5 km in Taiwan, the radar data is well below the melting layer. In addition, considering the vertical profile of differential reflectivity is not well studied in the current stage, no vertical corrections are applied to fields of Z and Z_{DR}. Ground clutter is typically associated with a low correlation coefficient (ρ_{HV}), the ρ_{HV} threshold used in this work is 0.9, which can effectively remove those non-meteorological echoes such as ground clutter.

Line 163: On the other hand, stratiform precipitations are generally associated with a prominent bright band signature. The melting hydrometeors increase backscatter during stratiform rainfall, which can significantly enhance radar reflectivity. The bright band feature is one of the obvious indicators of stratiform precipitation. Bright band signature normally can be observed from relatively high EAs (such as above 9.9°). From low EAs, because of the combination of radar beam broadening and low slant angle, the bright band feature spreads into more gates and becomes not apparent. Therefore, in this work, the bright band feature from high elevation angles is only used in training data selection but not used as one of the inputs.

4.) Section 2.3, in my opinion, it may useful cite some previous work that developed machine-learning algorithm based on meteorological radar data. I suggest the following reference: Capozzi et al. (2018), Adity Sai Srinivas et al. (2019) and Yen et al. (2019).

Response: Following the reviewer's suggestion, these three references were added into the revised manuscript.

Line 139: Machine learning algorithms based on meteorological radar data were well developed during the past two decades (e.g., Capozzi et al., 2018; T. et al., 2019; Yen et al. 2019)

5.) As training data for convective precipitation type, the authors use the measurements collected in a single event occurred on 23 July 2014. More specifically, for this event radar data collected from 10:30 to 11:30 (one hour) were used. I am quite skeptical about this choice, that the authors must justify and explain. It is well note that convective events may be triggered by different meteorological scenarios and that may exhibit different features in radar data according to thunderstorm types (single cell, squall line, supercell, etc.).

Response: In this work, the training data plays a critical role in the SVM development. Therefore, we choose convective and strtiform precipitations following three major steps.

1.) First, the training data was checked following general classification principles: for example, heavy precipitation band associated with high reflectivity for convective type precipitation; bright band for stratiform type precipitation.
2.) Second, the ground observation is used as another reference. For example, the severe weather report could be used as the ground observation.
3.) The classification results from MRMS is used as the third reference.

The convective type precipitation data is mainly from a thunderstorm on 23 July 2014. An aircraft crash tragedy caused by strong downdraft is used as the ground observation. MRMS classification algorithm classifies this event as the convective precipitation type. The radar observation of reflectivity Z and differential reflectivity Z_{DR} at 0858 UTC is shown in Fig. 2

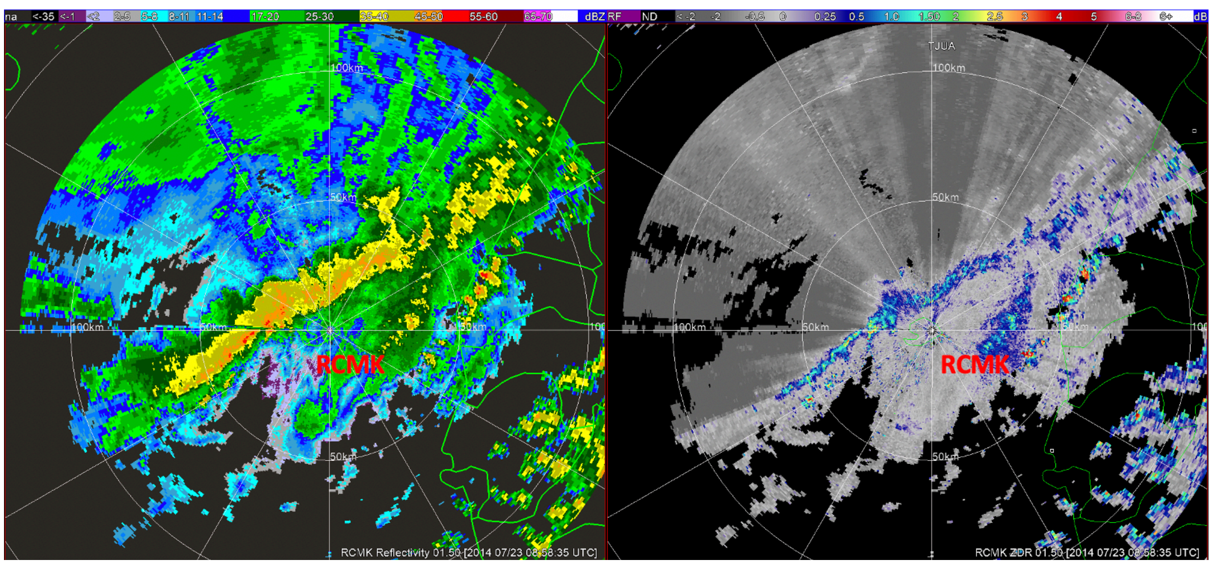

Figure 2. Reflectivity (left) and differential reflectivity (right) at 0858 UTC, 23 July 2014.

A clear squall line features can be identified at this moment, which triggered the strong updraft/downdraft. Inside this squall line, the reflectivity field is above 40 dB; differential reflectivity field is above 1 dB. The maximum value of Z_{DR} could be as high as 2.5 dB. Behind the severe precipitation band, the differential reflectivity field drops to negative value because of the attenuation issue. Fields of Z and Z_{DR} from 1028 UTC are shown in Fig. 3. Although the squall line signatures are not as well structed as 0858 at this moment, clear convective precipitation features such as large reflectivity, and very positive differential reflectivity are still very obvious. Therefore, we use those gates classified as convective type as in the training data.

We hope these plots can address the reviewer's concerns.

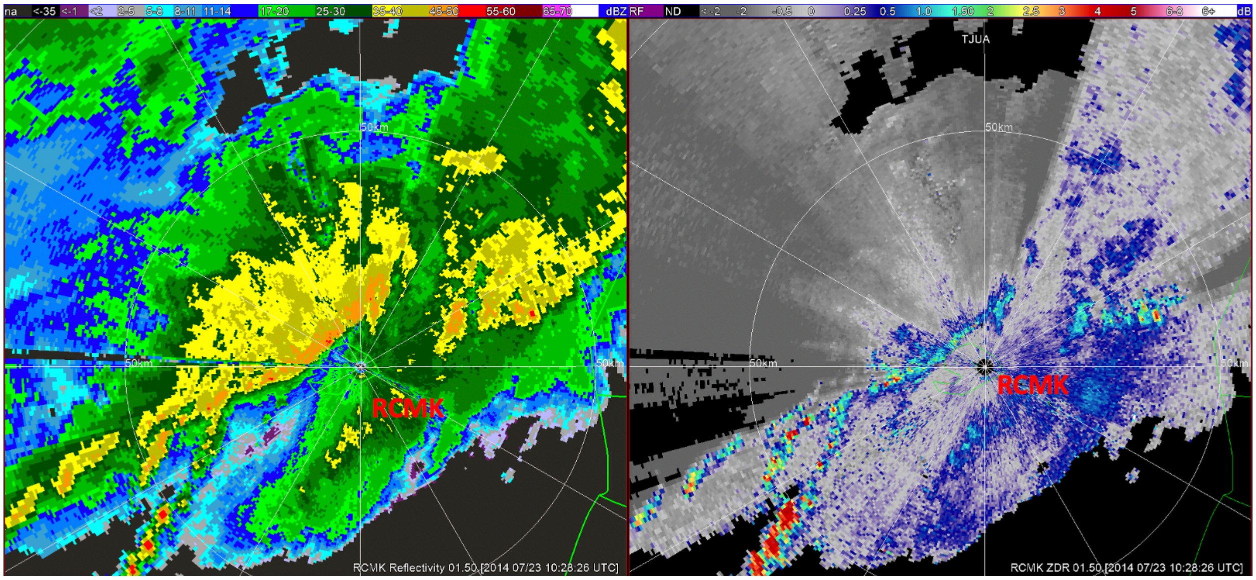

Figure 3. Reflectivity (left) and differential reflectivity (right) at 1028 UTC, 23 July 2014.

6.) Moreover, at page 6 (line 166) the authors declare that 17281 sets of data have been used in the training process. What does it mean "sets"? A clarification about this point is required.

Response: We appreciate the reviewer pointing this out. A "set" means a set of data from one radar gate (defined as azimuthal angle and range). Be more specific, a set of training data means a vector of $[Z(a,r)\ Z_{DR}(a,r)\ i(a,r); d(a,r)]$. Where "*a*" indicates azimuthal angle, "*r*" indicates range; "d" is the desired response with "1" represents convective, and "-1" represents stratiform.

Line 188: A total of 17281 sets of data (15144 sets of stratiform, and 2137 sets of convective) are used in the training process. In this work, one data set is defined as the variables from a single gate in terms of range and azimuthal angle. Be more specific, a collection of training data means a vector of $[Z(a, r)\ Z_{DR}(a, r)\ i(a, r)\ d(a, r)]$, where *a* and *r* indicate azimuthal angle and range, respectively. The variable *d* is the ground truth (with 1 and -1 represents convective and stratiform), i.e., the desired response in the training process.

7.) In section 3, the authors present the results of their work, introducing a whole coverage convective ratio (RCS) number. The latter is defined as parameter that provides a qualitative assessment of the performance of SVM and other considered methods. In my opinion, an evaluation about the reliability of SVM algorithm based on a single parameter is not sufficient to reach robust conclusions. Therefore, I suggest to involve in the statistical analysis other useful scores, such as the Critical Success Index and ROC curve.

Response: We agree with the reviewer that a single crietia may not sufficient to validate the performance of proposed approach. To address the reviewer's concerns, we made the following modifications:

1.) Besides the convective ratio (R^{CS}) we introduced in the original manuscript, we also applied the Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) in the performance evaluation.

2.) Since both cases of 30 August 2011 and 14 June 2012 are widespread stratiform and convective mixed precipitation events, and the performances of proposed approach show similarity from these two cases. We only kept the 30 August 2011 cases in the revised manuscript for the stratiform and convective mixed precipitation case. We also added more analysis and sensitivity test on this case.

3.) For the tropical precipitation case 08/06/2009~08/09/2009 case, we included POD, FAR, CSI analysis, and also included sensitivity test.

Please refer section 3 in the revised manuscript for more details.

8.) Some suggestions about figures. In figure 1, I suggest to include a reference scale for terrain elevation.

Response: Following reviewer's suggestion, a reference scale for terrain elevation is added in the manuscript, as shown below.

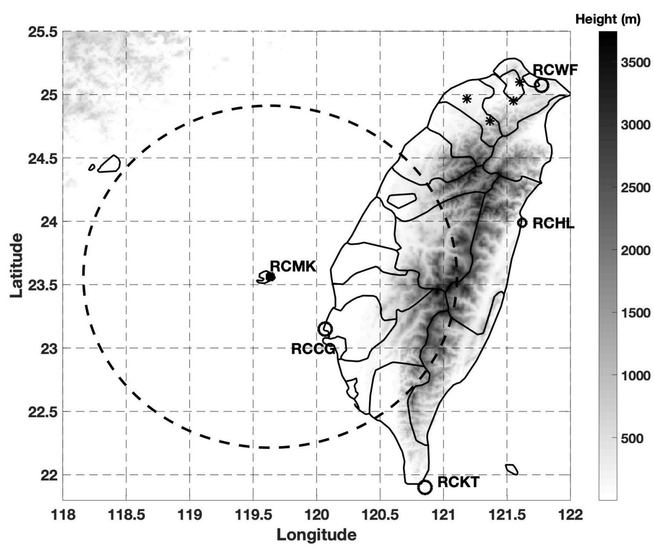

Figure 4. The terrain of Taiwan, the location of a C-band polarimetric radar RCMK (marked with a black square), JWDs (marked with black stars), and four S-band single polarization radar

RCCG, RCKT, RCHL, and RCWF (marked with black circles). The continuous grey-scale terrain map shows the central mountain range of Taiwan.

9.) In figure 3, it is necessary to improve the line-style used to indicate the various algorithm. More specifically, MRMS and SVM time series seem have a similar marker according to the legend showed in panel (a).

Response: Following reviewer's suggestion, we use different colors to represents the results from different algorithms. More details could be found from the response to comment 7.).

10.) Regarding figure 4, I recommend to enlarge the panels, if it is possible. Moreover, the color scale should not have a gradient, because the output of the algorithm is binary (convective or stratiform).

Response: Following reviewer's suggestion, we made following modifications: 1.) enlarge each panels in figure 4; and 2.) change the color scale as binary.

11.) About Figures 5, 6, and 7, please clarity in the caption the meaning of black, red, and white circles.

Response: Following reviewer's suggestion, we added the meaning of these circles in the caption.

12.) Finally, I suggest to carefully checking the paper to address some minor typos.

Response: Following reviewer's suggestion, we run grammar and spelling check before submitting the revision.