General answers to the Editor and to the two Referees

We want to express our sincere appreciation for all the comments and suggestion from the Editor and the two Referees. We have seriously examined all the suggestions from the Editor Dr. S. J. Munchak (i.e., impact of the parallax correction, and presentation of results in a more "physical" way, with a geographical map of the statistical scores and analysis of how the algorithm performs for different types of precipitating event). The comments on the readiness and organization of the results section have been particularly appreciated. The anonymous reviewer 2 has expressed some criticism on the need of a detection algorithm and on the possibility to have consistent detections from different sensors. Well argued criticisms like these makes it possible for an author to think about the real motivations of his work, and present them in a clearer form. Finally referee 1 comments have pointed out several issues on our manuscript that have been addressed, i.e. we particularly appreciated the comments on the minimum detectable rainfall from PR, the choice of using the same dataset for training and testing and the need of a more physical analysis. Moreover we acknowledge referee 1 for the "*labor limae*" (a patient, diligent, meticulous work) on our manuscript.

In order to address all the referees and editor comments we have made substantial changes in the manuscript. In detail, we have built an independent dataset of coincident observations relative to the year 2013 and used this dataset for the testing of the algorithm. As a consequence all the results section is now relative to this new test dataset. Moreover we have removed the SSMIS radiometer on board the DMSP-F18 satellite both from the training and the test datasets because of the presence of a corrupted channel at 150 GHz. As suggested by the Editor, we have made comparisons with the results obtained calculating the Canonical Variables (CVs) in log(RR) space (where RR is the rainfall rate) finding better performances of the algorithm. Therefore, we have decided to adopt a new discrimination function based on CCA in log(RR) space. Finally we investigated the impact of the parallax corrections on the results finding a very small impact and decided not to apply any parallax correction. In order to meet the suggestion of a more physical analysis of the results we have computed a table of the statistical scores divided by rain type as observed by TRMM-PR and by the background surface. Finally, we have analyzed the impact on the algorithm of the non uniform beam filling effect.

These main changes are hereafter briefly reported:

A. **Changes in the text relative to the dataset construction and partition, and to the change of the discriminant function:**
    1. P9243 L4 changed to "AMSU/MHS radiometers in the years 2011-2013"
    2. P9243 L24: changed to "and DMSP-F17 satellites (i.e. the DMSP-F18 has the 150 GHz channel malfunctioning since February 2012)".
    3. P9246 L1 a sentence that describes the dataset partition in training and test will be inserted at the end of Section 2: " The SSMIS and AMSU/MHS datasets have been divided into a training set (which includes all data from 2011 and 2012) and a test dataset (data from 2013)".
    4. P9246 L2: a sentence describing the use of the training dataset at the beginning of section 3 will be inserted: "This section is dedicated to the training of the CCA algorithm done by using the training dataset relative to the years 2011-2012".
    5. P9247 L2; the sentence "correlation with rainfall rate (RR)" will be replaced by "correlation with the logarithm of rainfall rate log(RR)".
    6. P9249 L8: a sentence that describes the use of the test dataset at the beginning of section 4 will be inserted: "This section shows the results of the application of the algorithm to the test dataset relative to year 2013."
    7. P9270: Figure 3 will show the results on the new training SSMIS dataset.

B. **Parallax corrections**:
   Descriptions and comments will be removed after the verification that there is a very small effect on the statistical scores due to the correction of the parallax effect (See answer to the Editor, E6, and to Reviewer 1, R1.5).

C. **Results Section:**

We have changed substantially the section "4. Results". The full new results section with new figures and tables can be found in the attached document "new_results_section.pdf". The main changes are listed below:

1. Figure 4-5 will be replaced with new figures, showing the results on the test and training datasets of the CCA algorithms and the comparison with other well known screening algorithms. The comments to these figures will be consequently modified, shortened and grouped into a sub section "4.1 Discussion of Skill Scores".

2. Figure 7 will be removed and a new figure (Figure 5) has been added to section 4.1 The new figure shows the well known POD, FAR and HSS. The results are shown for rain/no-rain threshold ("truth" from PR 2A25) equal to 0.1 mm/h. Skill scores relative to CCA-GMI have been removed because they almost identical to CCA-SSMIS. A comment on this figure will be included in section "4.1 Discussion of Skill Scores".

3. Figure 6 and Table 3 will be changed. The comments to this figure and table will be modified accordingly into a new subsection: "4.2 Minimum Detectable Rate".

4. New tables will be inserted in the manuscript in a new subsection "4.3 Dependence on precipitation regime".

D. Changes in the conclusions:

1. The conclusions have been updated with the new results.

Specific answers of the authors to the Editor Comments

We acknowledge the Editor for the useful and constructive comments.

General comments:

E1. I found the method described in this paper quite simple yet robust in its ability to detect precipitation over a variety of surfaces and applicability to a variety of instruments. The focus of the analysis section is on a statistical discussion of results and comparison to other methods. This section is difficult to read and could benefit from some improved organization starting with division into three subsections (discussion of skill score beginning on page 9250, line13; minimum detectable rate beginning on page 0252, line 26,;and impact on total rainfall estimate beginning on page 9254, line 28). Also, the very long paragraphs on 9251 and 9253 should be shortened; as they stand they simple serve to describe Figures 4-6 but with only a few features meriting further discussion. Here, I found the high level of detail interrupted the narrative, so to make the section more readable I suggest that some of these details can be omitted from the text (but still present in the figures themselves) without affecting the discussion.

Thank you for your suggestions. We agree, and we have rewritten this section by dividing it into three subsections (4.1 Discussion of skill scores, 4.2 Minimum Detectable Rate, 4.3 Dependence on precipitation regime), and by shortening the paragraphs and the comments to the Figures. Figure 5 has been added in Section 4.1, while the part relative to impact on total rainfall estimate has been removed (see Comments and answer E2 below).
The modified sub-sections 4.1 and 4.2 and the new sub-section 4.3 are reported in the "new_results_section.pdf" file.

E2. I also found the discussion on the affect of detection on total rainfall unclear. It seems to be based on the use of the algorithm only as a screen without deriving precipitation rates (although this should be readily available from the CCA procedure). I understand the concept of the "perfect algorithm" as described, but what is the meaning when FPH+FPF is much greater (or less) than 1? Does that imply that the algorithm actually overestimates (or underestimates) rainfall?

We agree, this discussion was unclear, and, as noticed also by Reviewer 2, the definition of FPF was questionable. Therefore, we have decided to remove the discussion and Figure 7. The discussion of a new figure (which has become Figure 5), where the standard POD, FAR and HSS for all algorithms are presented, has been included in section “4.1 Discussion of skill scores”.

E3. As mentioned above, the focus seemed to be on the statistical interpretation of the results; it would be helpful to have a more physically based analysis as well (although perhaps this would be the subject of a companion manuscript). In particular I would be interested in a map of the false alarms and misses over each surface type to see if they are clustered geographically or associated with a particular type of precipitation (ie, shallow warm rain) or environmental variable (e.g., surface temperature or water vapor). This may be beyond the scope of the present work, however.

We want to thank the editor especially for this suggestion. We have performed some new analysis based on the TRMM rain_Type flag that will be included in section “4.3 Dependence on precipitation regime” (see the attached file “new_results_section.pdf”). As far as the possibility of showing the geographical map of the statistical scores of the CCA algorithm, please see answer R1.1 to Referee 1.

Specific corrections:

E4 9239 line 3: DPR stands for Dual-frequency Precipitation Radar

Done

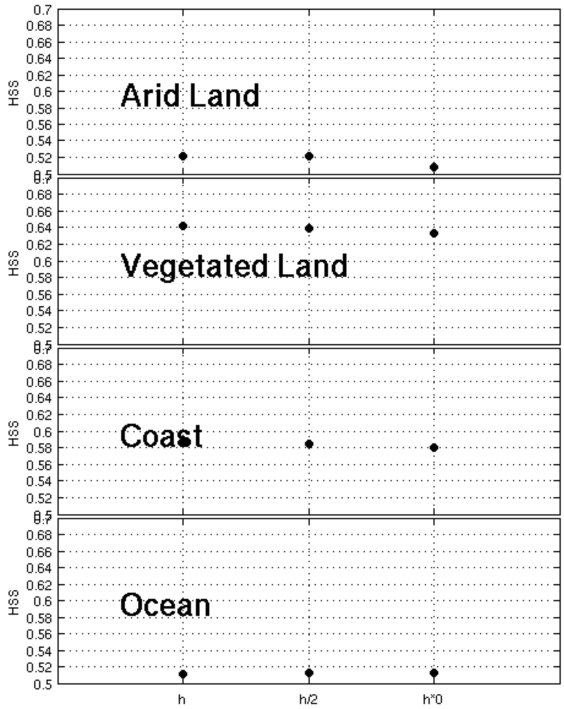
E5 9239 line 11: AMSR2 is onboard GCOM-W1, not Megha-Tropiques

Done

E6 9245 line 15: PR minimum sensitivity is 18 dBZ (not 0 dBZ), which is the value that should be used to define echo top. However, since the radiance is an integral function, it does not come exclusively from the cloud top but is weighted through the precipitation column. This weighting function varies by frequency and precipitation intensity. The result is that the parallax effect should be somewhere between zero and that implied by the ds=h*tan. To account for this effect properly the authors should perform the weighting differently for each pixel, but at the very least it would be informative to perform a sensitivity test generating the database with no parallax and ds=0.5*h*tan_.

The 0 dBZ minimum sensitivity was a mistake and we are sorry for that.

We have performed the test the Editor suggests, finding small differences between the *1*h*, *0.5*h* and the *0*h* parallax correction. In detail we have checked the HSS over various surface types calculating the parallax shift based on a cloud height equal to *1*h*, *0.5*h* and the *0*h* (with *h* defined in the original manuscript as the cloud top echo from the PR reflectivity profile). The following figure shows the test on parallax correction for SSMIS radiometer. We have found a small impact on the results and we decided to remove the parallax correction from our dataset and from the manuscript.



In Section 2 (“ Instrument and dataset description “) of the revised version of the manuscript the part on the parallax correction will be removed (P9245 L9-25). In case the Editor recommends it, we will add a brief comment on the lack of a significant impact of parallax correction for this study based on the results of the test we have performed.

E7 9247, line 2: Was the CCAR procedure performed on rain rate in linear or log space? The response of Tbs is generally more linear with respect to log(R) than R, so this may make a difference in the results.

We thank the referee for this very useful comment. We have made comparisons with the results obtained calculating the Canonical Variables (CVs) in log(R) space (where R is the rainfall rate) finding better performances of the algorithm. In detail we have performed the same analysis shown in figure 3 for the choice of the discriminant function (calculating the CCA_R for the candidate discriminant functions 4-7 of table 1 on the training dataset) computing the correlation with log(R). The resulting functions have been analyzed in a discriminant analysis and compared in terms of HSS with the original results. This comparison (for CCA_R function only) is shown in the following table:

	HSS of CCA_R in R space	HSS of CCA_R in Log(R) space
Arid Land	0.5049	0.5185
Vegetated Land	0.6011	0.6035
Coast	0.4637	0.5164
Ocean	0.5235	0.5763

Therefore, we have decided to adopt a new discrimination function based on CCA in log(R) space. The results in figure 3 relative to the CCA_R calculated in linear R space have been replaced with the new results.

9256 line 20: The pseudo-GMI channel set also does not include dual polarization at 166 GHz which may also be critical for the detection of light precipitation

We agree, we will add the following new paragraph in sub-section 4.2:

Regarding the pseudo-GMI dataset, it is worth noting that it was generated from the SSMIS dataset only by discarding the channels not available in the GMI radiometer (183+-1 GHz and the 50-60 GHz band channels). Therefore the results can be representative of the performance of a CCA algorithm for the real GMI radiometer only to a certain extent, since we have considered only the instrument observation geometry *(conical scanning) and some of the channels frequencies and polarizations. The presence of the 10 GHz and 166 GHz channels with both polarizations on GMI (not available on SSMIS) might have a significant impact on precipitation detection. Moreover, the higher spatial resolution of GMI with respect to SSMIS sensors has not been considered, and it may strongly affect the results on real GMI data. It is worth noting that the almost identical results obtained for the SSMIS and pseudo-GMI datasets indicate that the inclusion of the sounding channels 183+-1 GHz and 50-60 GHz has no impact on the CCA precipitation detection.*