Response to Reviewer 2

We thank the anonymous referee for very thorough and constructive comments. Below are our responses to the comments.

Reviewer2

This study provided a method to retrieve total precipitable water and cloud liquid water path over ocean using observations from FY-3D MWTS and MWHS. It was very useful to extend the usage of FY-3D measurements. However, there are still several questions.

1) The major part of this manuscript was to generate brightness temperature of two frequencies at 23.8 and 31.4Ghz. However, as I know, FY-3D MWRI provides vertical and horizontal observations at 23.8Ghz, why not use these observations directly for the retrieval of TPW and CLW?

Response: MWTS, MWHS and MWRI are different microwave loads on FY-3D, and their corresponding spatial resolution and instantaneous field of view are completely different. MWTS and MWHS are mainly used to observe the vertical structure of the atmosphere, while MWRI is mainly used to observe the surface parameters.

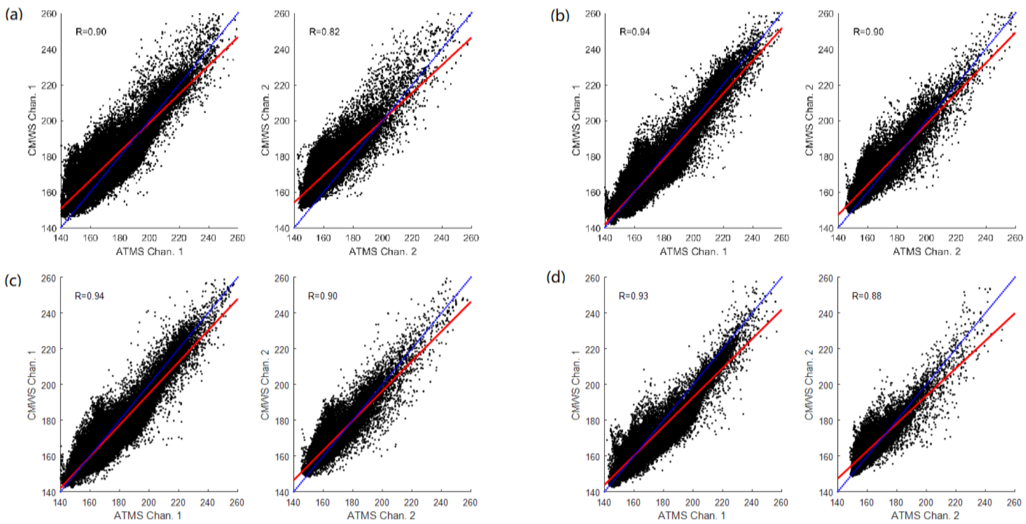
The purpose of this paper is to extend the application of FY-3D microwave sounding data by using existing TPW and CLW inversion methods so that it can be successfully assimilated into the numerical weather prediction system. To invert TPW and CLW from microwave measurements, both statistical inversion and physical inversion methods need the information of 23.8 and 31.4GHz channels.

In satellite remote sensing, the observations obtained by different sensors are difficult to be used interchangeably, and they need to undergo strict cross calibration and footprint matching. Although MWRI can provide observations at 23.8GHz, it still lacks the measurements at 31.4GHz. If we want to directly use the observations of MWRI, we need to add an additional cross calibration and footprint matching process. Especially, due to the need to meet the requirements of time and space consistency, the footprint matching between different sensors often results in the loss of many pixels, which will introduce more uncertainty.

2) The manuscript said that the mean absolute errors of the two simulated channels are both between 3 and 4K, I want to know how much errors will be caused in the retrieved TPW and CLW when using the simulated channels.

Response: We added some quantitative assessments in the revised manuscript. A total of five days of data were selected as data sources from different months. Since ATMS and CMWS have different field of view (FOV) and satellite transit times, to perform pixel-to-pixel accuracy assessments, we need to collocation all pixels to ensure that the same pixels are evaluated. Successfully matched pixel pairs need to meet the following parameters: imaging time difference is less than 30 minutes, space distance is less than 15KM, satellite height angle difference is less than 10°, and scanning angle difference is less than 20°. After collocate all the ocean pixels from 60°S to 60°N, a total of 180,906 pixels were used for quantitative evaluation.

First, we compared the brightness temperature simulation accuracy of Ch1 and Ch2 when FY-3D observations are used as input in the machine learning model. Figure R1 shows scatter plots between ATMS and CMWS of two corresponding channels. The scatter results for five different dates are shown in (a) to (e), respectively. Subplot (f) represents the total scatter results. Overall, the accuracy and stability of the two channel simulation are satisfactory. According to the five-day observation results from different months, the correlation coefficient of Ch1 is more than 0.9, and the correlation coefficient of Ch2 is also close to 0.9. It should be pointed out that the results of machine learning using FY-3D observations as input will definitely be lower than the accuracy of quantitative evaluation using ATMS measurements as input. This is because the cross calibration between ATMS and FY-3D will inevitably introduce some new errors. Quantitative evaluation results can be found in Table R1. The mean absolute errors of the two channels between ATMS and CMWS are 6.74 and 5.73K, respectively.



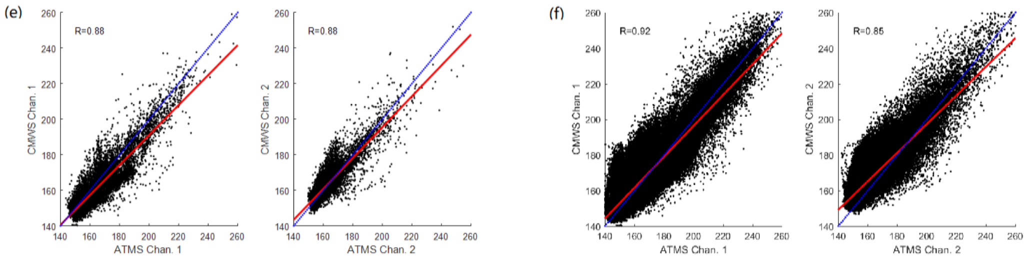


Figure R1. Scatter plots for ATMS channels and CMWS channels. (a) June 2, 2018, (b) July 2, 2018, (c) August 2, 2018, (d) September 2, 2018, (e) October 2, 2018, (f) All collocation pixels.

Second, we compared the retrieved TPW and CLW using the same retrieval method for ATMS and CMWS, respectively. Figure R2 shows scatter plots of retrieved TPW and CLW based on ATMS and CMWS, respectively. Also, the scatter results for five different dates are shown in (a) to (e), respectively. Subplot (f) represents the total scatter results. The results of quantitative evaluation show that the correlation coefficients of TPW and CLW between CMWS and ATMS are 0.95 and 0.85, respectively, and the mean absolute errors are 5.14mm and 0.1mm. Moreover, the correlation coefficients and mean absolute errors during the five independent days are very close, which shows that the method proposed in this paper has good stability and robustness (see Table R1).

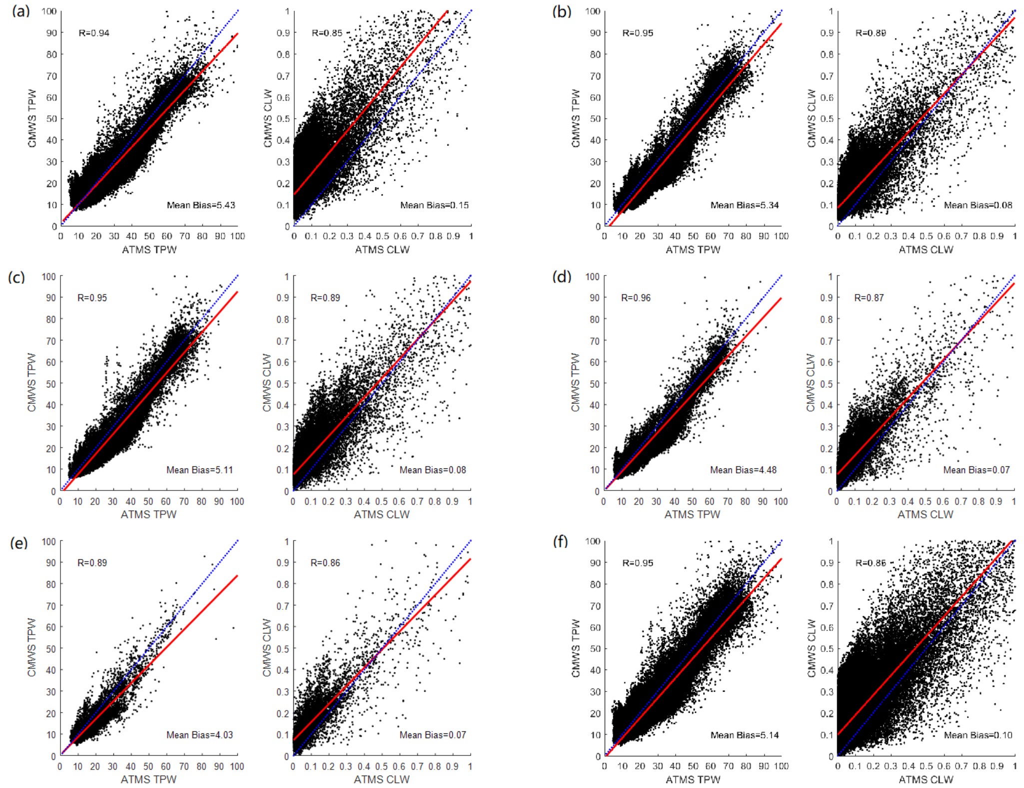


Figure R2. Scatter plots of retrieved TPW and CLW based on ATMS and CMWS, respectively. (a) June 2, 2018, (b) July 2, 2018, (c) August 2, 2018, (d) September 2, 2018, (e) October 2, 2018, (f) All collocation pixels.

Table R1. Quantitative evaluation results between ATMS and CMWS

Date (2018)	Matched pixels	Correlation Coefficient				Mean Absolute Error			
		Ch1	Ch2	TPW	CLW	Ch1 (K)	Ch2 (K)	TPW (mm)	CLW (mm)
June 2	54,831	0.90	0.82	0.94	0.85	7.27	8.66	5.43	0.15
July 2	53,322	0.94	0.90	0.95	0.89	6.75	4.4	5.34	0.08
August 2	40,565	0.94	0.90	0.95	0.89	6.24	4.60	5.11	0.08
September 2	22,955	0.93	0.88	0.96	0.87	6.37	4.62	4.48	0.07
October 2	8,936	0.88	0.88	0.89	0.86	6.61	3.77	4.03	0.07
Total	180,609	0.92	0.85	0.95	0.85	6.74	5.73	5.14	0.10

3) In the cross calibration section, only two days data were used in the cross-calibration between ATMS and CMWS. How the authors guarantee the stability of cross calibration relationship between ATMS and CMWS.

Response: The prerequisite for cross calibration is to ensure that the cross-calibration point pairs meet the same observation time and the same observation point. To cross calibrate different sensors, we first need to perform footprint matching. However, Suomi NPP and FY-3D satellites have completely different orbit altitudes and transit times. Most of the time, the same observation point that two sensors can match is very limited.

Fortunately, the sub-satellite trajectories of Suomi NPP and FY-3D satellites are very close each other on February 1-2, 2018, which allows us to use the data of these two days to cross-calibrate ATMS and CMWS. Although we only used two days data, the number of points successfully matched exceeded 100,000 pairs, and they covered the world evenly, including different weather around the world, which is very representative. Once the cross-calibration relationship between different sensors is determined, the mapping relationship between them will not change greatly as long as the sensors do not show severe aging.

4) There are lots of TPW observations from SuomiNet GPS network and RAOB network on small islands. It will be helpful if these observations were used to validate the retrieved TPW.

Response: Thanks for the reviewer’s suggestion. Due to the influence of satellite transit time, very few observation points can be matched between the satellite and the ground observations. Considering that the TPW and CLW inversion methods adopted in this paper have been successfully applied in ATMS, we mainly performed comparisons between different satellites to verify the results.

In addition to the qualitative comparison used in the original manuscript, we added some quantitative assessments in the revised manuscript. For specific comparison results, please refer to our reply to the second question of the reviewer.