Response to Editor

Dear Editor & Prof.

We greatly thank you and the two reviewers for the thorough and valuable suggestions to our work. The manuscript has been polished and modified by professional organizations, and English has been greatly improved. We have made a point-to-point response to these opinions and suggestions, and believe that the quality of the manuscript has been promoted now. All comments have been modified and added in the revised manuscript (mark with blue font), and the responses to each comment are given below.

Thank you very much for considering our work!

Yours sincerely,

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Response to anonymous Referee#1

1. Lines 144 - 147 are not clear.

Therefore, $P_{new}(\lambda,r)$ is denoised by wavelet transform, threshold function is a soft threshold, wavelet base is sym7, and the number of decomposition layers is 5. Using wavelet function to reduce noise can avoid too much smoothing remove sharp signal changes due to clouds, and can also avoid the improper selection of moving average window.

Answer: Lines 144 – 147 are re-described as,

Therefore, wavelet denoising is used to deal with $P_{new}(\lambda,r)$, select symlets7 wavelet base as the wavelet decomposition basis function, the decomposition layer is 5, and the threshold value is the heursure based heuristic threshold value provided by MATLAB. Compared with the smooth function, wavelet denoising can avoid eliminating cloud signals with steep changes due to too much smoothing.

2. I think the units (%) for fig 16 in the revised manuscript are not correct, I believe these could be normalized units 0 to 1. I suggest the authors to check for proper units.

Answer: We have redefined the units of figures 16 and 18, and should not need the unit %. The Fig 16 has been changed in the manuscript.

3. Why the cloud cover shown in fig 17 is now high for December compared to the previous version?

Answer:

The cloud cover of the previous version was obtained by using the data of December 2021, and the cloud cover shown in fig 17 in the response and revised manuscript was obtained by using the data in December 2020. We have explained in the previous response document that the data from January to December 2021 be replaced by December 2020 to November 2021 (and divided into four seasons).

4. Line 426: the frequency of high-level ice clouds above 8 km is small. Is this due to the detection limit of the radar, if so please mention it?

Answer: The frequency of high-level ice clouds is small may be caused by the detection limited sensitivity of MMCR to small particles.

The corresponding content is added in lines 125-162 of the paper, as shown below，

L426-429: “Combined with the changing characteristics of cloud layers, it can be seen that during observation in Xi'an, the frequency of clouds below 3.5 km is the largest, and the frequency of high-level ice clouds or cirrus clouds above 8 km is small. ” **and can be re-described as:**

L428-431: “Combined with the changing characteristics of cloud layers, it can be seen that during observation in Xi'an, the frequency of clouds below 3.5 km is the largest, and the frequency of high-level ice clouds or cirrus clouds above 8 km is small, which may be due to the limited detection sensitivity of MMCR at the top of high-level clouds where the particles size are very small.”

5. Again, please check if the units are (%) for fig 18?

Answer: Figure 18 does not need the units (%), which has been changed in the manuscript.

Response to anonymous Referee#2

1. Line 64-65: “take” needs to be replaced with “mistake”, “underestimated” should be “underestimation”.

Answer:

“…but this method takes some real signals at the cloud bottom as noise and miss information at the cloud top, and resulting in overestimation and underestimated…”**and can be re-described as:**

“…but this method mistake some real signals at the cloud bottom as noise and miss some information at the cloud top, and resulting in overestimation and underestimation…”

2. Line 105: Please check “HT101”, which is “TH101” in the response.

Answer: Sorry, it's a writing error in the response, and the “TH101” in the response should be “HT101”.

3. Line 145: What is the full name of “sym” in “sym7”? It should be clarified.

Answer: Line 145: “sym” is the abbreviation of symlets, which is wavelet basis function, and has been described in the manuscript.

4. Line 153: Please add detailed description of the “baseline 1”and the “baseline 2” in the manuscript, and what is the difference between them?

Answer: Add description of baseline 1 and baseline 2 in lines 153-155, as follows,

Line 153-156: Get *Pnew-sp-smooth* after smoothing $P_{new\_sp}(\lambda,r)$. The slope K_1 of *baseline-1* obtained from the points (15, V1) and (endpoint, V2) on *Pnew-sp-smooth*, and *baseline-2* got by using K_1 and point (starting point, V0) as shown in Fig. 3b) and Fig. 4b).

5. Figure 3: Fig. 3c shows the vertical profile of SNR. However, "S" is marked on the horizontal axis. I'm confused whether it is the abbreviation of SNR and why the unit of S is “N”.

Answer:

1) Fig. 3c) *SNR* in Shannon formula is the power ratio of signal to noise, which is a dimensionless unit. It has been explained in the response document, but Fig. 3c and Fig. 4c in the manuscript are flawed. Figures 3 and 4 are redrawn as follows.

2) Line 164, where N is the pulse accumulation, and P_{back} is the solar background noise power, **and can be re-described as:**

where N is the pulse accumulation, P_{back} is the solar background noise power, and *SNR* in Shannon formula is the power ratio of signal to noise, which is a dimensionless unit.

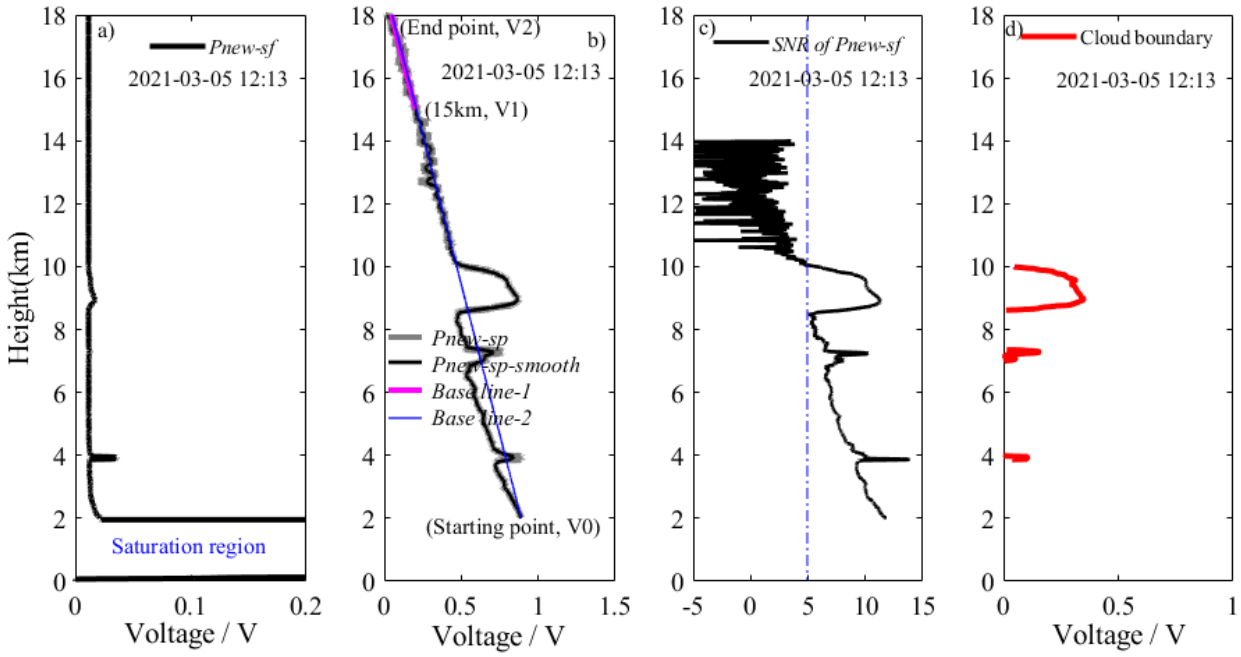

Fig. 3 Detection results of lidar at 12:13 on March 5, 2021. a) P_{new_sf} of the 1064 nm signal, b) P_{new_sp} of the 1064 nm signal, c) *SNR* of P_{new_sf}, d) cloud information detected

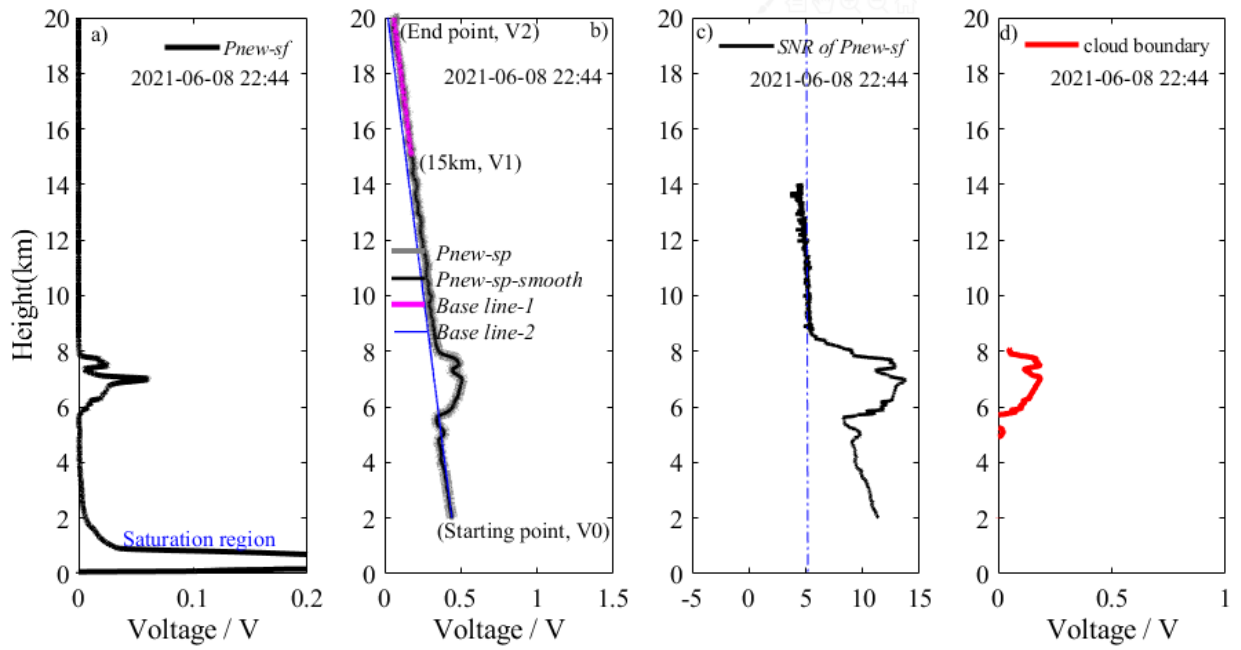

Fig. 4 Detection results of lidar at 22:44 on June 8, 2021. a) P_{new_sf} of the 1064 nm signal, b) P_{new_sp} of the 1064 nm signal, c) *SNR* of P_{new_sf}, d) cloud information detected

6. Line 184-185: “two parts” appears twice in this sentence.

Answer:

There are two parts in Fig. 6 includes two parts: recognition of cloud signals from Doppler spectra of MMCR and data quality control for MMCR, **and can be re-described as:**

Fig. 6 includes two parts: recognition of cloud signals from Doppler spectra of MMCR and data quality control for MMCR.

7. Line 203-205: Why you choose reflectivity of 20dBZ, velocity of 0.2m/s and spectra width of 0.3m/s as the thresholds?

Answer:

We use a large number data of MMCR in cloudless sky (ensure that it is the echo signals generated by planktonic) to analyze the numerical-frequency distribution characteristics of signals (reflectivity factor, radial velocity and velocity spectral width) in the range of 0 – 2km. We get that the reflectivity factor frequency is mainly distributed below -20 dBZ, the radial velocity is mainly distributed at -0.2m.s ~ +0.2m/s, and the velocity spectral width is mainly distributed above 0.3m/s. Therefore, we establish thresholds for eliminating signals of planktonic in the manuscript.

8. Line 214: There is no "Fig. 6b" in Figure 6, please check.

Answer:

The noncloud signals at the bottom (0–2 km) are effectively eliminated using the quality control algorithm shown in Fig. 6b), **and can be re-described as:**

The noncloud signals at the bottom (0–2 km) are effectively eliminated using the quality control algorithm shown in 2) of Fig. 6, and the accurate recognition of cloud boundary is realised in Fig. 7d).

9. Line 251: "The microwave radiometer accurately records the rainfall time" is mentioned, but the "similar to the following" is difficult to understand. The specific rainfall time recorded by the microwave radiometer should be illustrated.

Answer:

1) Line 251: at 06:00 CST (The microwave radiometer accurately records the rainfall time, similar to the following)**, and can be re-described as:**

   at 06:00 CST (the microwave radiometer accurately records the rainfall time)

2) Line 279: the low-level cloud rained from 18:30 to 18:45 CST**, and can be re-described as:**

   the low-level cloud rained from 18:30 to 18:45 CST (the rainfall time is obtained by checking the microwave radiometer),

3) Line 332: When rainfall occurs (at 10:45 CST), **and can be re-described as:**

   When rainfall occurs (the microwave radiometer showed that rainfall occurred at 10:45 CST),

10. Line 258: The dotted line in Figure 8 is blue instead of "black". The color bars for a), b) and c) in Fig 8, Fig.10 and Fig.12 should be labeled with unit.

Answer:

The blue lines in Figs 8 and 10 have been changed to black lines. Corresponding units have been added in color bars of figures 8, 10 and 12. The units of color bar for a) in figures 8, 10 and 12 are dimensionless, and units of the color bars for b) and c) in figures 8, 10 and 12 are voltage / V.

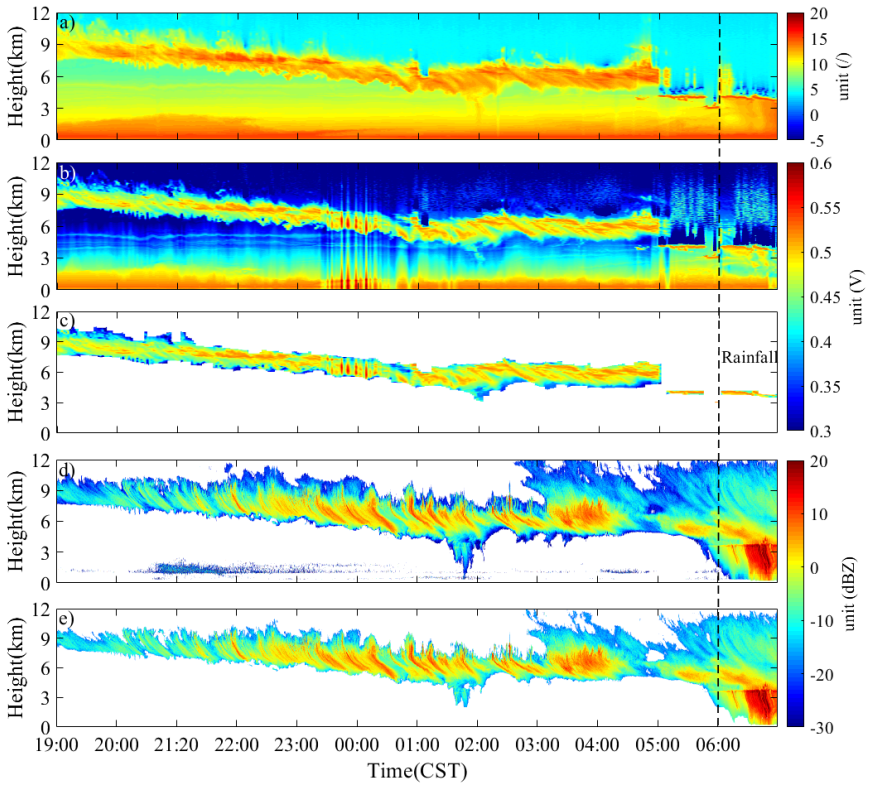

Fig. 8 THI of the echo signal of the lidar @1064 nm from 08 to 09 June 2021. a) *SNR* of P_{new_sf}, b) P_{new_sp} of the 1064 nm signal, c) cloud information detection results from lidar, d) reflectivity factor without quality control, e) reflectivity factor with quality control (black dotted line indicates rainfall time)

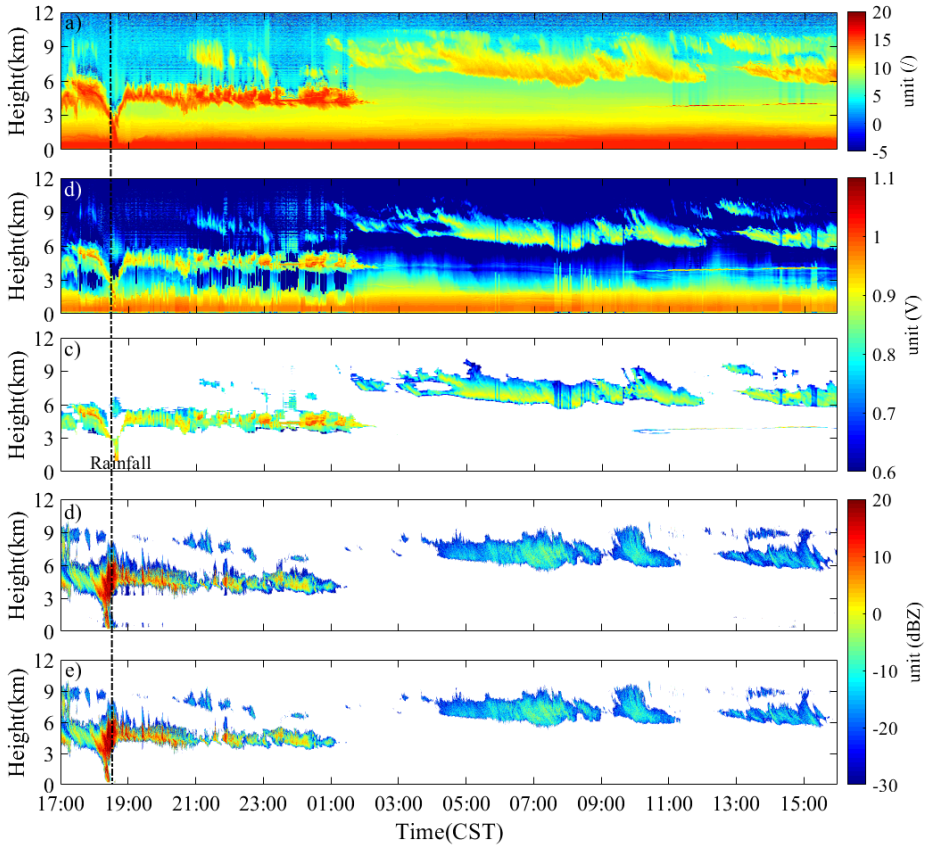

Fig. 10 THI of the echo signal of the lidar @1064 nm from 4 to 5 March, 2021. a) *SNR* of P_{new_sf}, b) P_{new_sp} of the 1064 nm signal, c) cloud information detection results, d) reflectivity factor without quality control, e) reflectivity factor with quality control (black dotted line indicates rainfall time)

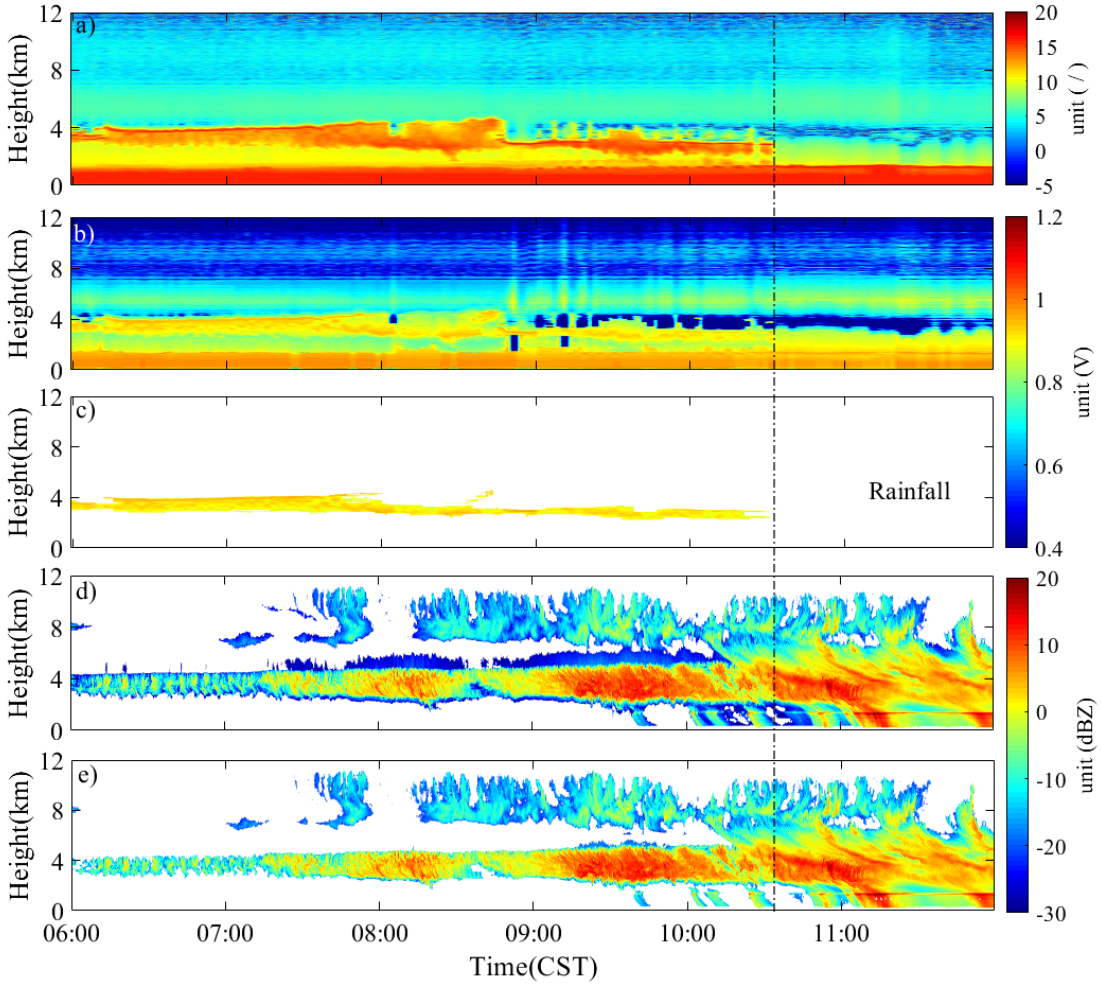

Fig. 12 THI of echo signal of the lidar and MMCR on 10 March, 2021. a) *SNR* of P_{new_sf}, b) P_{new_sp} of the 1064 nm signal, c) cloud information detection results, d) reflectivity factor without quality control, e) reflectivity factor with quality control (black dotted line indicates rainfall time)

11. Figure 13: In the response version, the authors claim that "because there are a larger number of plotted points, the cloud bottom height around 0 km is appropriate", one should note that the bottom echo signal is not the height of the cloud base for precipitating cloud. If this height is treated as the cloud base, the frequency distribution of cloud base height in the manuscript may not be reasonable.

Answer: Sorry, we didn't clearly describe this problem in the response version. Our original intention is to express that in Figure 13, there is rainfall after 11:00 CST, and the reflectivity factor of MMCR has touched the ground. In this case, cloud bottom recorded by MMCR is 270 m instead of 0 m, and the cloud bottom is invalid according to the cloud bottom height recording guideline of case 5 in Table 3. Therefore, in Figs 16 and 18, we do not count the cloud bottom height of precipitating clouds measured by MMCR.