Response to Editor

Dear Editor & Prof.

We greatly thank you and the two reviewers for the thorough and valuable suggestions to our work, and thank you valuable comments and suggestions by peer experts in the open discussion. We have made a point-to-point response to these opinions and suggestions, and all the comments have been addressed in the revised manuscript. We believe that the quality of the manuscript has been promoted now. The responses to each comment are given below.

Thank you very much for considering our work!

Yours sincerely,

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Response to reviewer

General Comments:

This study operated advanced observation of columnar condensation water in the air, which is significant for studying the hydrologic cycle and the assessment of cloud water resources. I recommend full peer-review. If possible, I would like the author to add more case analysis. In addition, the language of the paper is too Chinglish, I suggest to invite a native English speaker to polish it.

Comments 1: If possible, I would like the authors to add more case analysis.

Response: More case analysis may have a better effect on explaining atmospheric phenomena. This paper mainly provides an observation method and technology of atmospheric column condensate. Other cases have also been observed and calculated, but we think there is no great difference between these cases according to the results. The case provided in this paper can prove the correctness of the method provided. The other case is shown below. Stratiform clouds were observed by lidar and millimeter-wave radar during the period in June 7, 2021, during this period, a weak rainfall process occurred, and the clouds dissipated later. The THI of cloud layer are shown in Fig. 1. The Fig.2 shows the temperature of cloud base and top. The Fig. 3 shows the time series of vertical wind velocity at the cloud base and cloud top. And Fig. 4 shows the instantaneous water vapor flux remaining in the cloud layer. Fig.5 shows the maximum possible condensate during the observation period. Compared these figures with the figures (Fig.7 to Fig.13) in the manuscript, different observation cases show similar results. No more case analysis is added in the revised version.

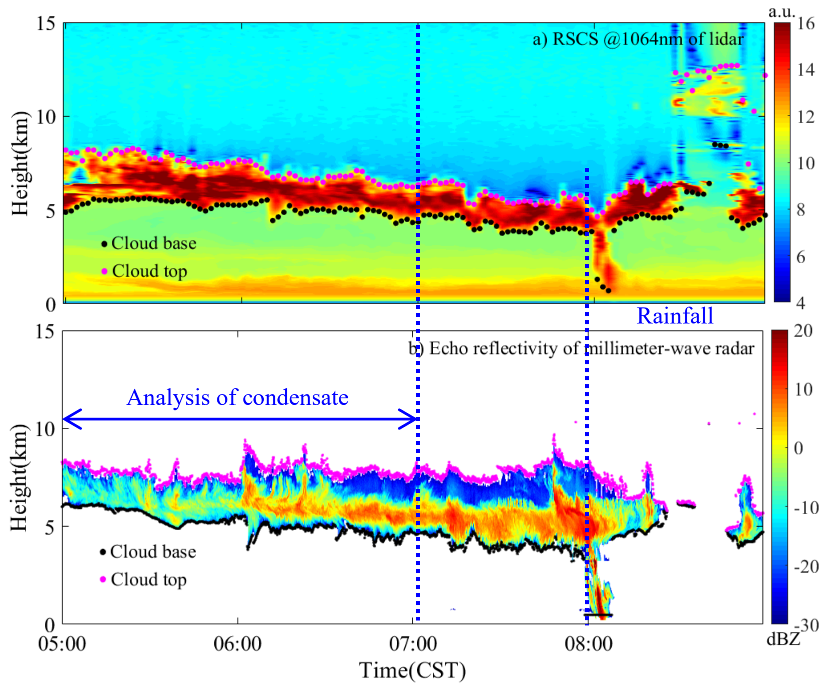

Figure1: Time-height-indicator (THI) plots of the range-squared-corrected signal (RSCS) observed by lidar at 1064 nm; (b) time-height-indicator (THI) plots of reflectivity observed by millimeter-wave radar

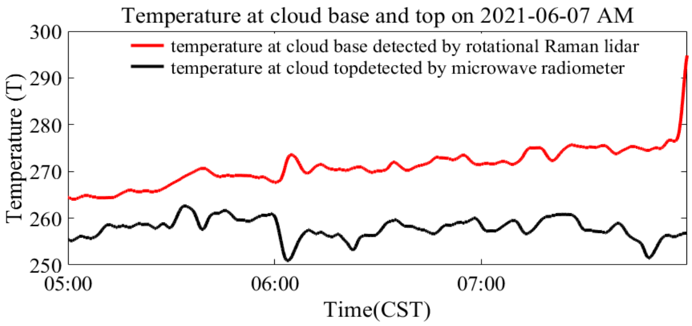

Figure 2: Time series of temperature at the cloud base and top

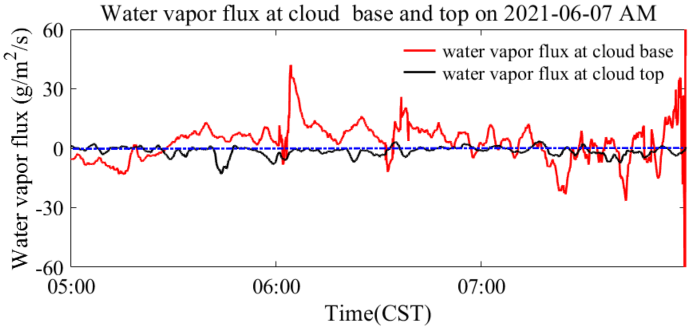

Figure 3: Time series of vertical wind velocity at the cloud base and cloud top

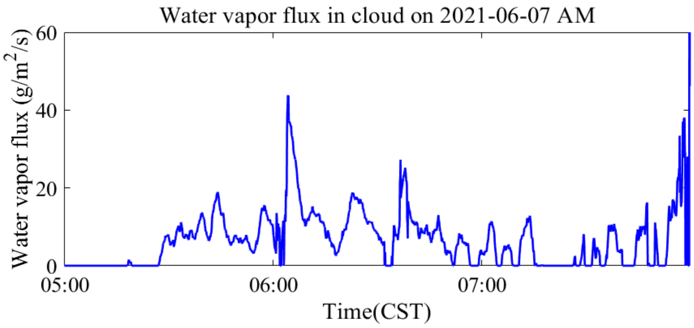

Figure 4: The instantaneous water vapor flux remaining in the cloud layer

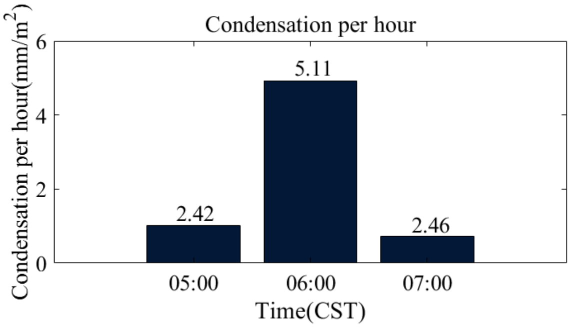

Figure 5: Hourly condensate during the observation period

Comments 2: In addition, the language of the paper is too Chinglish, I suggest to invite a native English speaker to polish it.

Response: Thank you very much for pointing out this issue. The manuscript has been polished and inaccurate phrases and sentences have been modified. "columnar condensation water" in the manuscript has been modified to "atmospheric column condensate"

Response to reviewer #1 (in open discussion)

General Comments:

This study presents an observation method for detecting atmospheric column condensates by combining millimeter-wave radar (MWR), lidar and microwave radiometers. This work is interesting and meaningful. Especially, the authors stated that it is the first application to operate observations of atmospheric column condensates. However, there are some issues in this manuscript, as listed below, that need to be carefully considered. Moreover, the English should be improved substantially, especially for Abstract and Results and discussions. I think this manuscript can be considered for publication only if the author could adequately address the comments below.

Response: We appreciate the reviewer's thoughtful review and constructive comments. All the comments have been addressed in the revised manuscript, and the responses to each comment are given below. The manuscript has been polished and revised by professional institutions, and I believe that the English has been improved greatly.

Specific comments:

1. Lines 16-18. The author specifically mentions stratiform clouds. Is their atmospheric columnar condensate calculated differently? Moreover, the atmospheric column condensate in stratiform clouds is calculated by the saturated water vapor density and vertical airflow velocity, but the saturated water vapor density is not mentioned in the later observed quantities in the abstract.

Answer: The main feature of stratiform cloud is that it has a large coverage and is relatively unified on the horizontal scale. The measurement results of one point can be used to represent the situation of a large area. However, the detection method provided in this paper is suitable for all types of clouds, not only for stratiform clouds, but also for convective clouds, and etc. This paper mainly provides a method for measuring air condensate. In order to avoid ambiguity, the "stratiform clouds" in Line 16 is deleted in the revised draft. The saturated water vapor density cannot be directly measured by remote sensing equipment. It can be derived by the temperature. The description is also added in line 20-21. The discussion about different types of clouds can be found in the last part (Line 364 to 379).

2. The authors keep emphasizing that it is "atmospheric column condensate", but the actual object of observation is cloud, so would it be more appropriate to change it to "cloud column condensate"?

Answer: The reviewer's suggestion is very meaningful. The actual object of observation is cloud, so Cloud column condensate should be correct and can be used. But we think "atmospheric column condensate" in this paper is more appropriate. From the perspective of metrology, the results expressed by atmospheric column condensate and cloud condensate are consistent. However, from the perspective of cloud water resources assessment, what we need to know is the condensate that may be generated in an atmospheric column. Of course, this condensate is mainly measured after cloud formation. Atmospheric column condensate can better express this meaning.

3. Figure 1. The authors should provide appropriate explanations for the schematic diagram. g., it is not clear whether the horizontal arrows of "Input or output airflow" represent total input or output, or just the horizontally oriented input or output.

Answer: The reviewers are rigorous. The appropriate explanations for the schematic diagram of Fig.1 have been added in Line 74-76.

4. Lines 116-117. To my knowledge, the unit of saturated water vapor density is g/m^3. Please check it.

Answer: Sorry, I made a clerical mistake. The reviewer was right. the unit of saturated water vapor density is g/m^3. It has been revised in the text in Line 124.

5. Lines 123-125. Please define R_v and give a reference to the equation's source. Furthermore, e is the water vapor pressure, and its unit should be similar to hPa, not kg/m^3. Please check it.

Answer: Sorry, I made a clerical mistake. The reviewer was right. The water vapor pressure's unit, not kg/m^3. It has been revised in the text in Line 131.

6. Figure 2. P_{cong} means the net flux from t1 to t2, so the label "Columnar condensation water" in the figure seems inappropriate.

Answer: Columnar condensation water is obtained by integrating the net water vapor flux from t_1 to t_2. A step is missing in the original figure and has been added.

7. Lines 182-183. Does the overline mean sum or average? What's more, the formula is valid on the assumption that the detection errors of S and V do not vary with time and are independent of each other. This should be declared in advance.

Answer: The overline mean the average of parameters in a short measurement period, which has been added in Line 193. Formulas 9 and 10 are valid on the assumption that the detection errors of S and V do not vary with time and are independent of each other. This has been declared in Line 189-190.

8. Figure 6. It seems difficult for the reader to understand in detail how the vertical velocity is obtained from the schematic. Additional instructions need to be provided.

Answer: Assuming that the vertical motion of the atmosphere is uniform during MWR detection, the Doppler velocity from small to large corresponds to the particle size from small to large. The size distribution of supercooled liquid droplet is relatively narrow, their spectrum can be closely approximated by a Gaussian model. Then the first spectral point on the left side of the power spectrum represents the signal of the smallest particle that can be detected by the radar. If the particle is small enough, it can be used to derive vertical air motion. The specific schematic diagram has been added in the text.

The sizes of typical supercooled liquid droplets range from 5 to 20 μm. The terminal velocities are in the order of 0.03 m s^{-1} and 0.07 m s^{-1} for 10-μm and 50-μm liquid droplets, respectively. Given their negligible fall velocities, these cloud droplets can be used as tracers for air motions. In Doppler radar spectra the radar returns from liquid cloud droplets can be identified as a narrow peak around 0 m s^{-1}. The mean velocity of this peak can be used to derive vertical air motion. As the size distribution of supercooled liquid droplet is relatively narrow, their spectrum can be closely approximated by a Gaussian model.

9. Lines 255-260. Reflections from raindrops can interfere with the signal, so how much uncertainty is there in wind speed measurements in rainy conditions?

Answer: In case of heavy rainfall, the particle reflection does not belong to the Rayleigh scattering area, and the detection results may not be true and reliable. In case of drizzle, the power spectra of drizzle and cloud droplets will partially overlap. At this time, the wind speed can not be solved directly by the little particle tracer air motions method, and the power spectra of the two need to be further decomposed. Some literature (Frisch, A. S et al., 1995) studies show that the existence of drizzle will affect the cloud difference by nearly 36%.

Frisch, A. S. , C. W. Fairall , and J. B. Snider . "Measurement of Stratus Cloud and Drizzle Parameters in ASTEX with a Kα-Band Doppler Radar and a Microwave Radiometer." Journal of the Atmospheric Sciences 52.16(1995):2788-2799.

10. Lines 287-289. A result picture of the cloud phase state should be shown.

Answer: See the answer 11 below.

11. Lines 295-297. The results of the microwave radiometer should be displayed and validated in Sect. 6. Moreover, how was the final temperature determined in figure 10? Is it a combination of rotational Raman lidar and microwave radiometer measurements?

Answer: Yes, Figure 10 shows the combination of rotational Raman lidar and microwave radiometer measurements. This has been declared in Line 300 to 305.

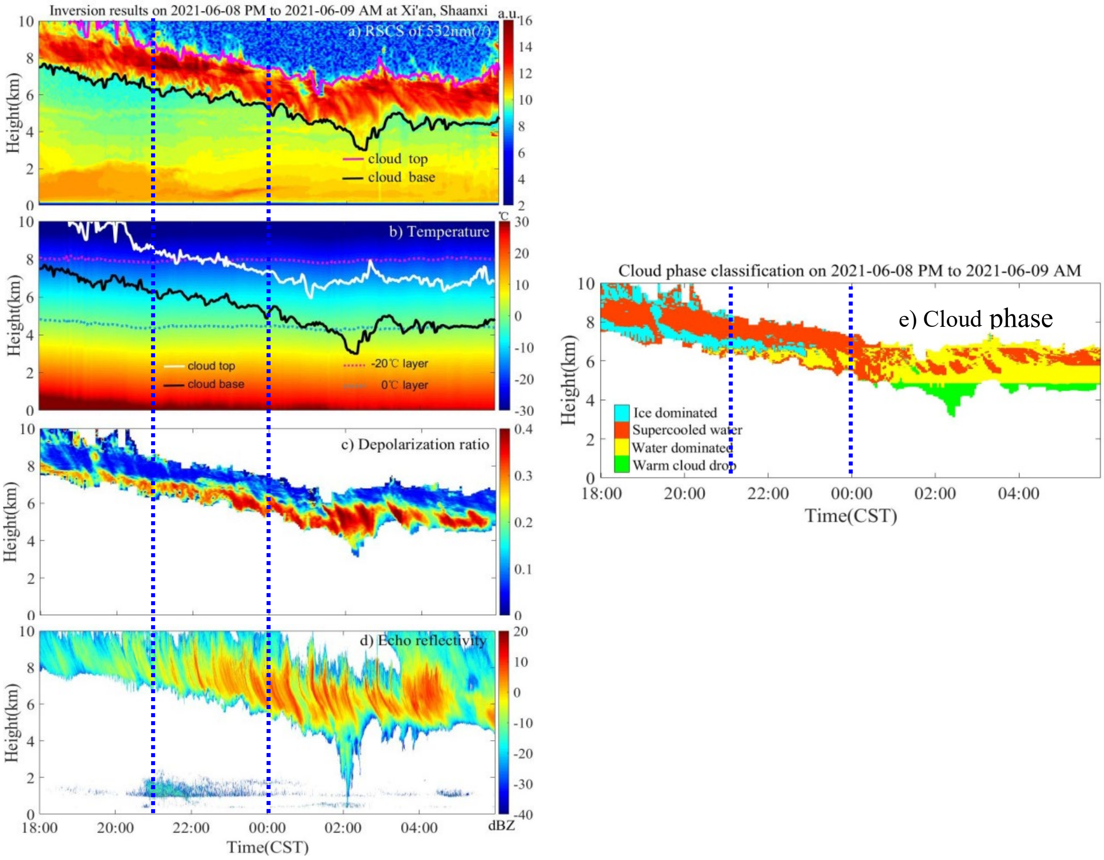

Figure 3 Cloud phase classification using multi-source ground-based remote sensing data

Answer: For questions 10 and 11: for this layer of precipitating cloud, we used multi-source ground-based remote sensing data to analyze the cloud phase in detail based on clustering algorithm, the results are shown in figure 1. Figure 3 (b) shows the temperature measurement results during the observation process by using rotating Raman lidar and microwave radiometer, and figure1 (e) shows the cloud phase recognition results. Supercooled water and water are dominant in the cloud layer from 21:00 to 23:59, but water is mainly distributed at the cloud base and top. Therefore, it can be used for the movement speed of the particle and characterize the vertical movement speed of the atmosphere.

12. Figure 12. The y-axis label "Condensation water" seems inappropriate, since it is the water vapor flux. And why are there only positive flux values in the figure?

Answer: The reviewer was correct, the y-axis label "Condensation water" is inappropriate, is has been corrected as "water vapor flux". Water vapor flux should have positive and negative values. The water vapor flux entering the cloud is recorded as positive, and the water vapor flux leaving the cloud is marked as negative. Only the water vapor entering the cloud may become condensate. Figure 12 only shows the water vapor flux into the cloud.

13. Lines 326-329. (1) The authors say that “the condensate in the period from 21:00 to 23:00 was integrated” and that “rainfall at 06:00 a.m.”, but what about the water vapor input and output from 23:00 to 6:00. It should be clarified. (2) According to the description, the total amount of the maximum possible condensate counted in this manuscript was 88.2 g (2.94 mm). The atmospheric column condensate can be obtained by integrating the instantaneous water vapor flux. It is worth noting that the unit of instantaneous water vapor flux is $g/m^2/s$, and its unit after integration with respect to time (s) should be g/m^2. This indicates in a physical sense how many grams of water vapor is transmitted per square meter (input or output). So I don’t understand how the authors got the results in g or even mm.

Answer: During the period of 21:00-23:59 (it is marked with blue dotted line in Fig. 8), the temperature and vertical velocity of the cloud boundary were detected, and the saturated water vapor density of the cloud boundary was calculated according to the temperature. The water vapor flux into the cloud during this period, that is, the maximum possible condensate, was deduced. From figures 7 and 8, the cloud bottom height keeps falling, indicating that water vapor is constantly replenished into the clouds and condensed water was generated. The column condensate after 23:59 is not calculated in this paper, mainly because the vertical velocity calculated by the minimum particle tracing method of millimeter wave radar is inaccurate, which will introduce large calculation deviation. These descriptions have been added to the Line 305-310 of the text**.** Thank the reviewers for their preciseness and seriousness, water vapor flux’s unit after integration with respect to time (s) should be g/m^2. This error has been corrected and revised in the text. "mm" is the unit used to describe the amount of rainfall in meteorology, what does it mean is “mm/m^2”.

Minor comments:

1. Line 36 and Line 65. The abbreviations need to be defined in the abstract and then again at the first instance in the rest of the text.

Answer: The full name of the abbreviation (CWR and MWR) has been added in Line 36 and Line 65.

2. Line 78. The right side seems to be GMh. This is not accurate.

Answer: “The right side” has been changed as “the middle”.

3. Line 162. The abbreviation RH is not needed because it is not used later. The same situation in photomultiplier tubes (PMTs), pure rotational Raman (PRR) and so on.

Answer: These unused abbreviations have been deleted in the revision.

4. Line 252. The W_{air} needs to be defined at the first appearance.

Answer: The error has been corrected.

5. Lines 269-270. The caption should be improved.

Answer: The error has been corrected.

6. Line 277. The name should not be all caps, also in Line 304.

Answer: The error has been corrected.

7. Figure 10. In the title of the picture, "… cloud topon …" should be "… cloud top on …". And drawing a 0-value line in the picture can better help the reader capture the information.

Answer: The error has been corrected.

Response to reviewer #2 (in open discussion)

General Comments:

This paper demonstrates a very interesting combined observation of atmospheric column condensate by using lidar, microwave radiometer, and millimeter-wave radar. The case study presented in this work opens up the feasibility for future research on the hydrologic cycle and the assessment of cloud water resources. The paper can be published after addressing following issues.

Answer: We appreciate the reviewer's thoughtful review and constructive comments. All the comments have been addressed in the revised manuscript, and the responses to each comment are given below.

Special Comments:

1. Since the abbreviations for microwave radiometer and millimeter-wave radar are similar, I would suggest use their full names in the whole manuscript. I was often confused about which technique MWR is referred to.

Answer: Indeed, the abbreviations of these two devices are easy to be confused. We accepted the suggestions of the reviewers and used their full names in the text.

2. Figure 2, maybe the coherent Doppler lidar should be removed from this figure, as it is not utilized in the present work.

Answer: "coherent doppler lidar and MWR" has been modified as "millimeter-wave radar or coherent doppler lidar". Both devices can be used to detect the air velocity at the cloud boundary. In this paper, the authors choose to use the data of millimeter wave radar.

3. I am not sure whether the number "237.3" is correct or mistyped.

Answer: The author confirmed that "237.3" is correct in equation 13.

4. Figure 8, maybe it is worth to add the cloud top in figure 8(a), particularly the part utilized in the evaluation.

Answer: The cloud top of millimeter-wave radar in Fig. 8 has been added.

5. Figure 9, it is better to add the information about the measurement technique for the temperatures at the cloud base or top in figure legends. On the other hand, what about the temperature at the cloud base measured by the microwave radiometer? Could that be used for the evaluation?

Answer: It has been noted in Fig. 9 that the temperature at the cloud base was detected by rotational Raman lidar, temperature at the cloud top was detected by microwave radiometer.

6. What about the measurement uncertainty of the vertical wind velocity, which seems to play a significant role on the final flux?

Answer： The vertical wind velocity plays a significant role on the water vapor flux and condensate. The uncertainty of the millimeter wave radar used in this paper is 0.3m/s. If Doppler lidar is used, the uncertainty of wind speed detection can reach 0.1m/s.

7. In this work, the author utilizes the saturated water vapor density for the evaluation. Could it be feasible to utilize the humidity measured by e.g., DIAL for the evaluation, which may improve the accuracy? A brief discussion about the feasibility could be valuable.

Answer: If the water vapor density at the cloud bottom can be measured, it can also be the evaluation of condensate. The author have compared the calculated saturated water vapor density at the cloud bottom by using temperature, which is consistent with the measured water vapor density at the cloud bottom by using water vapor lidar. It is difficult for lidar to detect water vapor in the day, it is difficult to obtain the water vapor density at the cloud top. While the measurement of temperature is relatively easy.

We have carefully revised the manuscript base on the opinions of reviewers and public discussion. The modified part has been marked with blue font. The specific modification list is as follows:

0) Modification the part of Abstract

Number	original manuscript	Number of line	revised manuscript	Number of line
1	cloud -water resources (CWR)	line 8	cloud-water resources (CWRs)	line 8
2	CWR	line 9	CWRs	line 9
3	CWRs include	line 10	CWRs include	line 10
4	at a time	line 10	at a certain time	line 10
5	CWR	line 13	CWRs	line 13
6	condensates, so	line 14	condensate evaluation, and	
7	CWR	line 14	CWRs	line 14
8	The method for detecting atmospheric column condensate in the atmosphere is proposed and presented	line 15	A detection method for atmospheric column condensate is proposed and presented	line 15
9	millimetre-wave radar (MWR)	line 19	millimeter-wave radar	line 19
10	The detailed detection scheme and data calculation method are presented, and the presented method can realize the deduction of atmospheric column condensate	line 20-21	The saturated vapor density can be derived by the temperature, and then, water vapor flux and the maximum possible condensate can be deduced. A detailed detection scheme and data calculation method are presented, and the presented method can realize the determination of atmospheric column condensate.	line 20-22
11	was monitored;	line 22	is considered	line 23
12	was deduced	line 22	is deduced	line 23
13	to operate observations of atmospheric column condensates	line 23	of observations for atmospheric column condensate evaluation	line 24

1) Modification the Chapter 1

Number	original manuscript	Number of line	revised manuscript	Number of line
1	world's surface	line 26	Earth's surface	line 27
2	increasing water	line 28	increasing in water	line 29
3	freshwater resources all come from precipitation	line 29	freshwater resources all originate from precipitation	line 30
4	It arises from evaporation of the oceans, lakes and rivers, which is then transported within the atmosphere and condenses into clouds	line 32-33	The former process arises from evaporation of oceans, lakes and rivers, and water vapor is then transported within the atmosphere and condenses into clouds	line 33-34
5	it precipitates to	line 33	water is precipitated onto	line34
6	also termed cloud water in both liquid and solid phases	line 34	also referred to as cloud water in both liquid and solid phases	line35-36
7	has experienced the second phase change and	line 35-36	has experienced the secondary phase change and has	line37
8	CWR	line 36-37	CWRs	line38
9	water vapor in the air can	line 42	water vapor in air can	Line43
10	precipitate to the ground	line 43	be precipitated onto the ground	Line44
11	CWR	line 43	CWRs	Line44
12	research on	line 44	research of	line 45
13	CWR	line 45	CWRs	line 46
14	The first step of exploiting CWR is to correctly evaluate CWR in an area, that is,	line 45-46	The first step of exploiting CWRs is to correctly evaluate CWRs in an area, that namely,	line 47
15	CWR	line 47-50	CWRs	line 48-51
16	The CWR is	line 51	The CWRs are	line 52
17	they mainly depend	line 51-52	these resources mainly depend	line 53
18	observations on	line 53	many observations of	line 54
19	and more.	line 56	and other factors	line 57-58
20	CWR	line 57	CWRs	line 58-59
21	is only a small part of the CWR	line 58	represents only a small part of the CWRs	line 59-60
22	major research instrument development project	line 61	Major Research Instrument Development project	line 63
23	a method for detecting atmospheric column condensate	line 64-65	a method of atmospheric column condensate detection	line 66-67
24	MWR	line 65	millimeter wave radar	line 67
25	atmospheric column condensation,	line 66	atmospheric column condensate	line 68

2) Modification of the Chapter 2

Number	original manuscript	Number of line	revised manuscript	Number of line
1	CWR	line 67	CWRs	line 69
2	in the cloud	line 68	in clouds	line 70
3	and potential	line 69	and the potential precipitation	line 71
4	beginning of a period	line 70	beginning of a given period	line 72
5	Fig. 1 shows a schematic diagram of CWR.	line 71	Fig. 1 shows a schematic diagram of CWRs. The horizontal arrows represent the cloud water horizontally oriented input or output from the cloud side boundary, the vertical arrow represents the cloud water coming in and out of the cloud top or cloud bottom through updraft or downdraft, and blue dots indicate the cloud water already in the cloud.	line 73-76
6	Figure 1: Schematic diagram of CWR	line 73	Figure 2: Schematic diagram of CWRs	line 78
7	atmospheric column	line 74	atmospheric column extending	line 79
8	be expressed by the following equation	line 75	be expressed follows	line 80
9	the right side is the expenditure item	line 78	the middle is the expenditure item	line 83
10	at time moments t1 and t2.	line 79	at time t_1 and t_2, respectively	line 84
11	over the time period	line 83	during period	line 87
12	*M*h1 at time *t*1, that is,	line 84	M_{h1} at time t_1, namely,	line 89
13	can be observed by	line 84	can be observed with	line 89
14	imaging spectroradiometer	line 85	spectroradiometer instruments	line 90
15	cloud water content on the boundary, which can be measured by wind profiler radar and cloud radar.	line 87-88	cloud water content, respectively, along the boundary, which can be measured by wind profiler and cloud radars, respectively.	line 93-94
16	For synoptic scale and mesoscale precipitation processes, the mass of the condensate is 100 times and 10 times larger than the cloud water input from the side boundary, respectively.	line 92-93	Regarding synoptic-scale and mesoscale precipitation processes, the mass of condensate is 100 and 10 times larger, respectively, than the cloud water input from the side boundary.	line 97-99

3) Modification of the Chapter 3

Number	original manuscript	Number of line	revised manuscript	Number of line
1	with liquid water	line 95	with containing liquid water	line 101
2	When the water vapor under the cloud	line 95-96	When water vapor below clouds	line 102
3	updrafts in cloud systems cannot be directly observed and quantified as in the above CLW.	line 98	updraft in cloud systems cannot be directly observed and quantified similarly to the above CLW.	line 104
4	can be considered adiabatic; therefore, atmospheric	line 99-100	can be considered adiabatic processes. Therefore, atmospheric	line 105-106
5	entering cloud layer	line 101	entering the cloud layer	line 107
6	if there is an updraft at the cloud top	line 102	if updraft occurs at the cloud top	line 108
7	velocity at the base and top of the cloud	line 104-105	velocity at the cloud base and top	line 111
8	Assume that	line 107	It is assumed that	line 113
9	so k is taken as 1 in this paper	line 108	so k is set to 1 in this paper	line 114
10	integrating it in a period of time	line 109	integrating the flux over this period	line 115
11	in formulas (2) to (5):	line 109-110	with Equations (2) to (5):	line 116
12	Here, p_{wv_in} is	line 115	where p_{wv_in} is	line 121
13	in the period from	line 116	during the period from	line 122
14	the unit is g/(m^2·s)	line 117	the unit is g/m^3	line 123
15	the subscripts "base" and "top"	line 117	the subscripts base and top	line 123
16	the upward value	line 119	an upward value	line 124-125
17	Rd is the constant of dry air and is 287.05 J/kg·K, T is the absolute temperature in units of K, and e is the water vapor pressure (kg/m^3).	line 124-125	R_d is a constant for dry air (287.05 J/kg·K), T is the absolute temperature (K), and e is the water vapor pressure (hPa)	line 130-131
18	$e_S(T)$ should be	line 129	$e_S(T)$ should reach	line 135
19	the temperature difference at	line 131	the temperature difference between	line 137-138
20	cloud layer is very thick (if > 3 km),	line 132	cloud layer is very thick (> 3 km)	line 138
21	be ignored; otherwise,	line 135	be ignored. Otherwise	line 141

4) Modification of the Chapter 4

Number	original manuscript	Number of line	revised manuscript	Number of line
1	Feasibility analysis of remote sensing observations for atmospheric column condensate	line 136	Feasibility analysis of remote sensing observations for atmospheric column evaluation	line 142
2	obtained for a period of time	line 137	obtained over a certain period	line 143
3	according to formula (6).	line 138	according to Eq. (6)	line 143
4	inside a cloud deck	line 141	within the cloud deck varies rapidly and greatly	line 147
5	very small	line 142	very low	line 148
6	detecting vertical airflow.	line 144	vertical airflow detection	line 150
7	Lidar has proven	line 145	The lidar has demontrated	line 151
8	MWR was also used for	line 147-148	the millimeter-wave radar has also used for	line 154
9	The detection accuracy of coherent lidar for radial velocity can reach the order of cm (Frehlich et al. 1994). Lidar can detect vertical air motions at the cloud base (Lottman et al., 2001), but due to the weak penetration of clouds and fog by the laser, the speed of the thick cloud top cannot be measured by lidar.	line 151-154	The detection accuracy of the coherent lidar regarding the radial velocity can reach the order of cm (Frehlich et al. 1994). Lidar instruments can detect vertical air motions at the cloud base (Lottman et al., 2001), but due to the weak penetration of lasers into clouds and fog, the speed of a thick cloud top cannot be measured by lidar instruments.	line 158-160
10	MWR	line 154	the millimeter-wave radar	line 161
11	It can measure	line 155	This instrument can measure	line 162
12	were derived from the MWR	line 156	can be obtained with the millimeter-wave radar.	line 163-164
13	in clouds for MWR.	line 157	with the millimeter-wave radar	line 165
14	resolution of MWR	line 157	resolution of the millimeter-wave radar	line 165
15	For convective clouds with higher rising speeds, MWR can also be used to detect the vertical air velocity at the cloud base.	line 159-160	Regarding stratiform clouds with low rising speeds, the lidar instrument should be used to detect the vertical air velocity at the cloud base. Regarding convective clouds with higher rising speeds, the millimeter-wave radar can also be used to detect the vertical air velocity at the cloud base.	line 166-167
16	relative humidity (RH) profiles.	line 162	relative humidity profiles	line 171

Number	original manuscript	Number of line	revised manuscript	Number of line
17	can be better than 1 K in low-altitude areas	line 164	exceed 1 K in low-altitude areas. Regarding thick clouds	line 173
18	Compared with lidar,	line 166	Compared to lidar instruments	line 174-175
19	Lidar, MWR and microwave radiometers need to be used together to realize the continuous observation of vertical air velocity	line 168-169	Lidar, millimeter-wave radar and microwave radiometers should be used together to realize continuous observation of the vertical air velocity	line 177-178
20	be obtained by lidar,	line 170	be obtained with a lidar instrument	line 179
21	The vertical velocity is measured by MWR.	line 171	The vertical velocity can be measured with the millimeter-wave radar	line 180-181
22	The temperature data from the sounding balloon	line 172	Temperature data retrieved from a sounding	line 182
23	Figure 2: Technical route of remote sensing observations for atmospheric column condensate 175	line 175	Figure 2: Technical route of remote sensing observations for atmospheric column condensate evaluation	line 185
24	MWR	line 176	millimeter-wave radar	line 186
25	will affect	line 177	can affect	line 187
26	the uncertainty of	line 179	the uncertainty in	line 189
27	They are determined by the uncertainty of the wind speed σv and the saturated water vapor density σS and yield	line 180-181	These errors are determined by the uncertainty in the wind speed σ_v and the saturated water vapor density σ_S and $\sigma_{p_{\mathrm{wv\_in}}}$ and $\sigma_{p_{\mathrm{wv\_out}}}$ can be written as the following equations on the assumption that σ_S and σ_v do not vary with time and are independent of each other.	line 190-192
28	The uncertainty of the saturated water vapor	line 184	The overline mean the average of parameters in a short measurement period. The uncertainty in the saturated water vapor	line 195
29	formulas (11) - (13):	line 185	Equations (11) to (13):	line 196
30	column condensate changes	line 189	column condensate varies	line 200
31	uncertainty of lidar at the cloud base is 0.5 to 1 K,	line 190	uncertainty of the lidar at the cloud base ranges from 0.5 to 1 K	line 201
32	less than 0.1 m/s.	line 190-191	lower than 0.1 m/s. Choosing spring	line 202
33	cloud base is approximately -3°C~-4°C.	line 192	cloud base ranges from approximately -3°C to -4°C	line 203-204
34	formulas (9)-(13).	line 193	Equations (9) to (13):	line 205

5) Modification of the Chapter 5

Number	original manuscript	Number of line	revised manuscript	Number of line
1	MWR	line 195	millimeter-wave radar	line 207
2	particle polarization characteristics, and more.	line 197	particle polarization characteristics, etc	line 209
3	MWR	line 198	millimeter-wave radar	line 211
4	The distance between these devices is approximately negligible compared with the observation target,	line 199-200	Compared to the observation target, the distance between these devices is approximately negligible	line 212-213
5	Figure 3: Installation of the equipment at the observation points	line 203	Figure 3: Installation of the equipment at the observation points	line 215

6) **Modification of the Chapter 6**

Number	original manuscript	Number of line	revised manuscript	Number of line
1	Remote sensing technology of atmospheric temperature and vertical airflow velocity	line 204	Remote sensing technology of the atmospheric temperature and vertical airflow velocity	line 216
2	Lidar	line 208	This lidar system	line 220
3	with a 9 ns FWHM	line 210	with the 9 ns FWHM	line 222
4	photomultiplier tubes (PMTs). Two pure rotational Raman (PRR) signals	line 213	photomultiplier tubes. Two pure rotational Raman signals	line 225
5	dichroic mirrors (DMs) and narrow-band interference filters (IFs)	line 215	dichroic mirrors and narrow-band interference filters	line 227
6	Lidar can detect temperatures of 0.5~5 km under clear sky or thin cloud conditions	line 216-217	The lidar system could detect temperatures at heights from 0.5~5 km under clear-sky or thin-cloud conditions	line 228-229
7	range-squared correction signals (RSCS)	line 219	range-squared-corrected signals (RSCSs)	line 231
8	It also shows	line 220-221	The figure also shows	line 233
9	to the inside of the cloud retrieved, and there is a good match between the lidar and radiosonde data.	line 222	to the inside of the cloud, and there occured a good match between the lidar and radiosonde data.	line 234-235
10	below 1 km has a large deviation.	line 223-224	below 1 km exhibited a large deviation	line 236
11	cloud base is less	line 226	cloud base was less	line 238
12	MWR for vertical airflow velocity	line 234	Millimeter-wave radar for the vertical airflow velocity	line 246
13	35 GHz MWR	line 235	35-GHz millimeter-wave radar	line 247
14	MWR	line 236	millimeter-wave rada	line 249
15	For micron-scale	line 238	Regarding micron-scale	line 250
16	very small	line 239	very low	line 250
17	Both vertical air motions and particle fall speeds	line 240	Both vertical air motion and particle falling speed	line 253
18	particle fall speeds	line 243	particle falling speeds	line 256-257

19	Such methods rely on	line 246	These methods rely on	line 259
Number	original manuscript	Number of line	revised manuscript	Number of line
20	the particle size–fall speed relationship	line 247	the particle size–falling speed relationship	line 260
21	about the presence of small particles,	line 249	on the presence of small particles	line 262
22	As shown by Wair in Fig. 6, it is the vertical velocity of the atmosphere.	line 251-252	Assuming that the vertical motion of the atmosphere is uniform during millimeter-wave radar detection, the Doppler velocity from small to large corresponds to the particle size from small to large. The size distribution of supercooled liquid droplet is relatively narrow, their spectrum can be closely approximated by a Gaussian model. Then the first spectral point on the left side of the power spectrum represents the signal of the smallest particle that can be detected by the radar. As shown in Fig. 6, W_{air} is the vertical velocity of the air.	line 265-269
23	interfering signals from	line 256	interfering signals resulting	line 272
24	rainfall velocities are different	line 259	rainfall velocities differ	line 277

7) Modification of the the Chapter 7

Number	original manuscript	Number of line	revised manuscript	Number of line
1	A case study for observation of atmospheric column condensate	line 261	Case study of the observation of atmospheric column condensate	line 278
2	by lidar and MWR during the period from	line 264	with the lidar and millimeter-wave radar during the period from	line 280
3	MWR.	line 265	millimeter-wave radar.	line 282
4	plots of reflectivity observed by cloud radar	line 270	plots of the reflectivity observed by millimeter wave radar.	line 285
5	rainfall; however, cloud changes	line 274	rainfall. However, cloud changes	line 289
6	MWR	line 274、276	millimeter-wave radar	line 290、292
7	the MWR are derived	line 277	the millimeter-wave radar were derived	line 293
8	Black points represent	line 277	The black points represent	line 293
9	MWR	line 278、279	millimeter-wave radar	line 294、295
10	in the observation time period	line 281	during the observation period	line 297
11	Their correlation analysis is carried out	line 281	Correlation analysis was carried out	line 297
12	the correlation is 0.9256	line 282	the correlation was 0.9256	line 298
13	two devices have a certain consistency on the macro parameters	line 282-283	two devices provide a certain consistency in the macroscale parameters	line 298-299
14	Cloud base heights detected by lidar and MWR.	line 285	Cloud base heights detected by the lidar and millimeter-wave radar	line 301
15	the cloud phase state also changes with the thickness and height of the cloud	line 286	the cloud phase state also changes with the cloud thickness and height	line 303
16	during the observation process	line 287	in the observation process	line 304
17	is a mixed phase state from 21:00 to 23:00 on June 8, 2021	line 289	was a mixed phase state from 21:00 to 23:59 on June 8, 2021	line 305

Number	original manuscript	Number of line	revised manuscript	Number of line
18	The base of the cloud is a liquid water area. In this detection period, the small particle tracing method can be used to accurately obtain the atmospheric vertical velocity (Wair), which can improve the accuracy of the condensate determination.	line 289-291	The base of the cloud was a liquid water area. During this detection period, the small- particle tracing method could be used to accurately obtain the W_{air}, which could improve the accuracy of condensate determination. During the period of 21:00-23:59 (it is marked with blue dotted line in Fig. 7), the temperature and vertical velocity of the cloud boundary were detected, and the saturated water vapor density of the cloud boundary was calculated according to the temperature. The water vapor flux into the cloud during this period, that is, the maximum possible condensate, was deduced. From figures 7 and 8, the cloud bottom height keeps falling, indicating that water vapor is constantly replenished into the clouds and condensed water was generated. The column condensate after 23:59 is not calculated in this paper, mainly because the vertical velocity calculated by the minimum particle tracing method of millimeter-wave radar is inaccurate, which will introduce large calculation deviation.	line 306-314
19	the time series	line 294	a time series	line 317
20	The microwave radiometer data	line 295	Microwave radiometer data	line 318
21	were checked by sounding balloon data,	line 296	were validated against sounding balloon data	line 319
22	The time series	line 297	A time series of	line 320
23	the MWR from 21:00 to 23:00 on June 8, 2021 by analyzing, the air vertical motion velocity at the cloud base and cloud top (positive upward and negative downward) was obtained by the small particle tracing method	line 300-301	the millimeter-wave radar from 21:00 to 23:59 on June 8, 2021, were ananlyzed, and the air vertical motion velocity at the cloud base and cloud top (positive upward and negative downward) was obtained via the small-particle tracing method	line 324-326
24	MATTHEW (MATTHEW et al., 2007).	line 304	Matthew (Matthew et al., 2007)	line 327
25	mainly an	line 305	mainly occured	line 327
26	Figure 10	line 307	Figure 10	line 307
27	The results are shown in Fig. 10.	line 303	As shown in Fig. 10	line 333
28	is approximately	line 310	was approximately	line 333-334
29	reducing the content of condensate in the cloud	line 312-313	reducing condensate content in the cloud	line 335-336

Number	original manuscript	Number of line	revised manuscript	Number of line
30	There is both water vapor entering from the cloud base	line 313-314	In this observation, both water vapor entering from the cloud base	line 336-337
31	the cloud is dissipating.	line 317	and if the flux is negative	line 340
32	Figure 11	line 319	Figure 11	line 342
33	Figure 12	line 322	Figure 12	line 344
34	From Fig. 11, the updraft at the cloud top was very small	line 325	As shown in Fig. 11, updraft at the cloud top was very limited	line 347
35	the condensate in the period from 21:00 to 23:00 was integrated, and it could be seen that the total amount of the maximum possible condensate in the atmosphere in this period was approximately 88.2 g (2.94 mm). The water condensed in this period provided	line 326-328	the condensate over the period from 21:00 to 23:59 was integrated, and it could be found that the total amount of the maximum possible condensate in the atmosphere during this period was approximately 88.2 g/m^2 (2.94 mm/m^2). The water condensed during this period provided	line 348-351
36	Figure 13	line 331	Figure 13	line 353

8) Modification of the Chapter 8

Number	original manuscript	Number of line	revised manuscript	Number of line
1	inside a cloud deck	line 335-336	inside the cloud deck	line 357-358
	MWR	line 357	millimeter-wave radar	line 359
2	the method proposed in this paper is still valuable.	line 342-343	the method proposed in this paper remains valuable	line 364-365
3	data of one point to	line 343	data at one point to	line 365
4	For clouds with strong convection	line 344	Regarding clouds with strong convection	line 366-367
5	Lidar is an effective instrument to obtain high-precision wind speed and temperature under clouds. Precipitation is a complex weather system	line 347-349	The lidar is an effective instrument to obtain high-precision wind speed and temperature data below clouds. Precipitation involves a complex weather system	line 369-371
6	The updraft before precipitation can be measured by MWR or lidar to obtain the "potential precipitation", that is,	line 351-352	Updraft before precipitation can be measured with the millimeter-wave radar or lidar to obtain the potential precipitation, namely,	line 373-374
7	if the precipitation is very weak,	line 353	if the precipitation is very low	line 376
8	lidar	line 353	lidar instrument	line 376
9	lidar will not be able to obtain effective data	line 354	lidar cannot obtain effective data	line 377
10	and a multilayer cloud structure will appear. Lidar usually cannot penetrate multilayer clouds, and it is only suitable for the detection of the base of single-layer clouds. For multilayer clouds, it is necessary to use MWR to detect the vertical air velocity	line 355-357	and a multilayer cloud structure can emerge. Lidar instruments usually cannot penetrate multilayer clouds, and these devices are only suitable for the detection of the base of single-layer clouds. In terms of multilayer clouds, it is necessary to use the millimeter-wave radar to detect the vertical air velocity	line 377-380
11	CWR	line 358	CWRs	line 381
12	which require long-term	line 358	which necessitate long-term	line 381
13	CWR	line 360	CWRs	line 383