Dear Referee,

I am very impressed by your so carefully checking and revising the manuscript. Thank you so much! I have carefully read all your question and suggestion, and modifications have been made in the manuscript. My replies are as follows.

General Comments

Overall, this paper contributes to an active and important area of study by investigating the microphysical characteristics of overshooting convection over East China. The techniques employed are reasonable and the results will be valuable for ongoing research in the area. However, the paper would benefit from a more detailed description of the methods, and various grammatical errors impact the flow and readability. Therefore, I suggest the following changes be made to the paper before publication.

Specific Comments

Introduction

(1) You mention the cold point and WMO tropopause definitions, but there is also the Dynamic Tropopause, which is based on the differing values of potential vorticity in the troposphere and stratosphere. I agree that the WMO tropopause definition is most suitable for identifying overshooting convection, but I might mention that there are three widely used definitions, rather than two.

Answer: Thanks for your advice! Dynamic tropopause has been added in this manuscript, meanwhile, I also find another new tropopause definition: ozone tropopause. And these two definitions have been added in the manuscript, shown as line 95-102 in the manuscript. The added references are shown as follows.

Danielsen, E. F., Hipskind, R. S. and Gaines, S. E. et al.: Three-dimensional analysis of potential vorticity associated with tropopause folds and observed variations of ozone and carbon monoxide, Journal of Geophysical Research: Atmospheres, 92(D2), 2103-2111, https://doi.org/10.1029/JD092iD02p02103, 1987.

Holton, J. R., Haynes, P. H. and McIntyre, M. E. et al.: Stratosphere-troposphere exchange. Reviews of geophysics, 33(4), 403-439, https://doi.org/10.1029/95RG02097, 1995.

Bethan, S., Vaughan, G., and Reid, S. J.: A comparison of ozone and thermal tropopause heights and the impact of tropopause definition on quantifying the ozone content of the troposphere, Quarterly Journal of the Royal Meteorological Society, 122(532), 929-944, https://doi.org/10.1002/qj.49712253207, 1996.

Zahn, A., Brenninkmeijer, C. A. M., and Van Velthoven, P. F. J.: Passenger aircraft project CARIBIC 1997–2002, Part I: the extratropical chemical tropopause,

Atmospheric Chemistry and Physics Discussions, 4(1), 1091-1117, https://doi.org/10.5194/acpd-4-1091-2004, 2004.

Data and Methods

(2) What is the reasoning behind the placement of the three regions? You mention their different climatic characteristics, but it would be good to be more specific about what these differences are. It would also be good to explain why you have limited the study area to the land.

Answer：Thanks for your question and advice!

1. Placement of the three regions is based on the study of Xia (2015). Using years of NCEP/NCAR reanalysis data, Xia (2015) analyzed the climatic feature of temperature and water vapor in China and divided China into different climatic zones. And we divided East China into three climatic zones according to Xia's study (2015). And this explanation has been added in the manuscript, shown as line 161-165.

2. For the three regions, the lower latitude areas have higher surface temperature, greater temperature lapse rate and lower temperature of stratosphere. Temperature profiles of same latitude are essentially same over SC and MEC, and temperature signals exist meridional differences over NC. Atmospheric humidity has remarkable regional characteristics, SC is wetter, with the surface relative humidity of more than 70%, while NC and MEC are drier and their humidity range from 50% to 70%. And this explanation has been added in the manuscript, shown as line 168-173.

3. Characteristics of vertical structure of precipitation over land and sea are very different. We have compared rain rate profiles between land and sea over SC, shown as Fig. 1, we can see that rain rate of convective overshooting over sea is much higher than land. This manuscript is limited in space and focuses only on the land region, a comparative study of convective overshooting over sea and land will be carried out in the future. And this explanation has been added in the manuscript, shown as line 158.

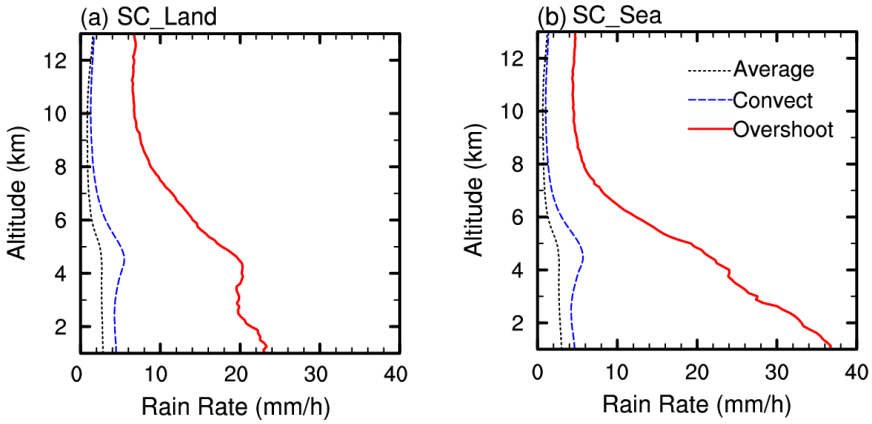

Figure 1 Rain rate profiles of Rain rate profiles for total precipitation, convective precipitation and convective overshooting over land and sea of SC. (a) The rain rate profiles over land of SC. (b) The rain rate profiles over sea of SC.

Xia, J.: Research on climatic regionalization of China and characteristics of temperature, humidity and wind in precipitation cloud, University of Science and Technology of China, 2015.

(3) Are you interpolating the ERA5 temperature profiles onto an altitude grid in order to calculate the tropopause height? The exact methods used to calculate the tropopause need to be explained in order for the results to be reproducible.

Answer：Thanks for your question and advice!

1. We are not use the method of interpolation. We use the principle of the nearest method to match the each pixels of GPM detection with ERA5 grid data. And this explanation has been added in the manuscript, shown as line 145.

2. The exact methods used to calculate the tropopause has been explained and shown as follows. And this explanation has been added in the manuscript, shown as line 145-155.

Firstly, match the each pixels of GPM detection with ERA5 grid data by using the principle of the nearest method. The marching time between GPM and ERA5 is 1 h, and the matching range is $0.25° \times 0.25°$. Storm top height is obtained from the GPM DPR. Convective overshooting is defined to occur where the storm top height is above the real-time tropopause height in a precipitation pixel.

Real-time tropopause height is calculated from the temperature profiles from ERA5 according to the definition from the World Meteorological Organization (1957). The algorithmic process is shown as follows: First, find X layer whose atmospheric lapse rate is 2 K km^{-1} or less by judging start from the first layer (near the ground) of the temperature profile, and then judge whether the atmospheric lapse rate does not exceed 2 K km^{-1} between the X level and all higher levels within 2 km, if so, the height of X layer is the tropopause height, if not, repeat the above algorithm starting from the X layer until tropopause layer is found.

Results

(4) Instead of saying ‘rain rates are mostly over 20 mm/h’, as in line 143, it would be better to provide a more quantitative result. You could calculate the mean rain rate for overshooting pixels, for example. This applies to the rain rates and storm top heights for the three case studies.

Answer: Thanks for your advice! The mean rain rate and storm top height for the overshooting pixels of the three case studies have been calculated and Modifications have been made in the manuscript, shown as line 181, 196, 191.

(5) In Figure 1b, I assume this is a climatological mean of the tropopause height? This should be stated for this and similar figures. Captions should include the time period over which these means are taken, which appears to be mentioned only in section 2.1. I would recommend specifying the study period in section 2.4 instead or in addition.

Answer: Thanks for your advice! Yes, Figure 1b show the climatological mean of the tropopause height, and we have stated that in captions of Figure 1b and in the text, shown as line 674-679. Time period was added in captions and section 2.4, and time period in section 2.1 was deleted, shown as line 174.

(6) In Figure 4, how is the distinction made between total precipitation and convective precipitation? Are these data sets complementary, or (for example) does the convective precipitation plot include values from overshooting pixels?

Answer: Thanks for your question!

1.The total precipitation represent the all pixels with rain rate higher than 0 mm/h detected by GPM DPR, and those pixels whose rain type are "Convective" are defined as convective precipitation. The detailed definition of total precipitation and convective precipitation are added in the manuscript, shown as line 227-229.

2. Convective precipitation plot include values from overshooting pixels.

Technical Corrections

Abstract

(7) 8 "We examine the geographical distribution and microphysical three-dimensional structure of convective overshooting over East China by comparing Global Precipitation …"

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 8.

(8) 13 "with a magnitude of only 10^-3;" This needs to be explained. It is not clear what it means without reading the paper. The semicolon most likely should be a period.

Answer: Thanks for your advice! Those words have been modified to "and its frequency varies from 4×10^{-4} to 5.4×10^{-3}" in the manuscript, shown as line 14.

(9) 14 “below the zero level” Recommend changing “zero level” to “freezing level” here and elsewhere.

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 15, 16, 271, 272, 278, 283, 285, 315, 340, 412, 413.

(10) 14 “SC (South China)” Recommend changing to “South China (SC)” for consistency with earlier abbreviation definitions.

Answer: Thanks for your advice! All abbreviation definitions have been changed for consistency. Modifications have been made in the manuscript, shown as line 12, 15, 129, 166, 257, 757.

(11) 15 Semicolon should be a period.

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 14, 17, 364.

(12) 17 “Droplets of convective overshooting are large, but sparse, with an effective droplet radius of nearly 2.5 mm below 10 km, which is about twice that of non-overshooting precipitation.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 18.

(13) 19 “humidifies air below the cloud top and increases ozone concentrations near the tropopause as a result of an influx of ozone from the lower troposphere and subsidence of high-ozone stratospheric air.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 22.

(14) 23 “as input for model simulations.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 28.

Introduction

(15) 38 “the effects of convective overshooting on the temperature of the UTLS has…”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 44.

(16) 41 “at the Earth’s surface, with important social and economic impacts”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 49.

(17) 43 “impacts, it is of high importance”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 50.

(18) 44 “overshooting, which have attracted considerable”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 51.

(19) 49 “efficiency of water vapor transport to the lower stratosphere”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 56.

(20) 54 “overshooting are larger than”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 61.

(21) 55 “characteristics of convective overshooting”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 62.

(22) 71 “that is to find pixels”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 78.

(23) 72 “which improves the”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 79.

(24) 81 “6-hourly dataset”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 88.

(25) 82 “geographical distribution; the microphysical”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 89.

Data and Methods

(26) 125 “2.3 Definition of convective overshooting” (remove ‘the’)

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 138.

(27) 126 “Convective overshooting is defined to occur where the storm top height is above”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 147.

(28) 127 “Storm top height” (capitalize beginning of sentence)

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 147.

(29) 129 “as follows:”

Answer: Thanks for your advice! These words have been deleted due to the rewriting of this part.

Results

(30) Figure 2: The black boxes used to indicate overshooting almost entirely cover the gridbox, making it difficult to read the intended information from the plots (rainrate, etc.). I would also state when the cases occurred in the main text, rather than the caption here.

Answer: Thanks for your advice! The black boxes are reduced to make the information about rain rate and storm top height clear, shown as Figure 2. The occurrence time of cases in the caption are deleted, and the time are added in the main text, shown as line 179-189, 683-690.

(31) You should indicate in the text that the locations of the three cases are shown on Figure 3.

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 196.

(32) 142 “Convective overshooting is observed in a total of 65 pixels for C1. Most overshooting pixels have rain rates exceeding 20 mm/h (Fig. 21), and storm top heights exceeding 12 km (Fig. 2b).” similar for case 2 (line 146) and case 3 (line 150)

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 179-190.

(33) 154 “characteristics of the large scale circulation for these three cases, we”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 194.

(34) 155 “shown in Fig. 3.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 196.

(35) 156 “In general, areas in which convective overshooting occur have abundant”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 196.

(36) 159 “The PWV of the region in which overshooting occurs is between 50 and 55 mm, which is higher than elsewhere (Fig. 3a)”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 199.

(37) 160 “Upward motion near the convective overshooting is strong, ranging from -0.03 to -0.12 Pa/s”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 201.

(38) 176 “tropopause height decreases and forms”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 218.

(39) 177 “height over NC is the lowest and”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 219.

(40) 185 “East China varies from”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 229.

(41) 192 “ranges from 10 km to 21 km (Fig. 4c), much higher than”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 236.

(42) 194 “Storm top heights of convective”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 238.

(43) 195 “which is due to a lower tropopause height (Fig. 1b) allowing convection with lower storm top height to penetrate the tropopause. This lowers the mean storm top height of convective overshooting in these regions, while tropopause heights over SC and southern MEC range from 16 km to 21 km (Fig. 1b), allowing only strong convection to penetrate the tropopause”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 239-243.

(44) 199 “above, an algorithm”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 244.

(45) 204 “with regional variation.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 249.

(46) 216 “overshooting is stronger and”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 262.

(47) 217 “also shows regional differences.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 263.

(48) 231 “overshooting is much higher,”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 277.

(49) 232 “5-10 times that of normal precipitation. This indicates stronger convection and a greater concentration of ice.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 277.

(50) 234 “Rain rates of convective overshooting over NC are about half as high as over MEC and SC”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 280.

(51) 239 “overshooting clearly decreases with increasing altitude, and rain rates are”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 286.

(52) 240 “rain rates of”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 287

(53) 248 “overshooting is clearly different”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 295.

(54) 250 “classified as downpour, while that of normal precipitation appears at ~1 mm/h, classified as moderate rain.”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 297.

(55) 274 “making it easier for convective overshooting to occur over northern MEC. This indicates that”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 321.

(56) 318 “has a humidifying effect on the air below the cloud top, humidifying MEC”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 365.

(57) 336 “overshooting increases ozone”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 383.

(58) 340 “decreases due to convective overshooting”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 387.

Summary and Conclusions

(59) 356 “events occur more frequently”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 403.

(60) 363 “is stronger”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 410.

(61) 364 “also shows regional”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 411.

(62) 389 “cloud top, humidifying MEC”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 437.

(63) 396 “and increase the ozone”

Answer: Thanks for your advice! Modifications have been made in the manuscript, shown as line 444.