Authors' comments on the first revision of the manuscript: "On the cross-tropopause transport of water by tropical convective overshoots: a mesoscale modelling study constrained by in situ observations during TRO-Pico field campaign in Brazil", Reviewer-1

We sincerely thank the reviewer for the pertinent and insightful comments that encouraged us to improve our manuscript. The point-by-point response to the reviewer's comments is documented here. The reviewer's original comments are listed. Italic and boldface fonts are used in the typesets. Each remark is followed by our response. When a change is made to the original version of the manuscript, the word "adjusted" is always included in the response. Unless otherwise specified, the line numbers, page numbers, figure numbers, and table numbers refer to the original version of the manuscript. We have also attached the revised version of the manuscript.

1 Minor Comments

1. ***L. 75: The authors should write the relative humidity with respect to ice.***

   adjusted - Line 75 of the text has been updated to include the RHi values from Khaykin et al. [2016].

   The text is now: "On that particular day, two lightweight balloon-borne hygrometers intercepted a hydrated stratospheric air parcel emanating from two distinct overshooting plumes. However, no ice particles were detected by the particle counter/backscatter sondes. It is also worth noting that at these altitudes, the relative humidity with respect to ice was reported to be about 40-50%."

2. ***L. 85: Are there several IOPs? If so, the authors should describe whole TRO-pico campaign very briefly.***

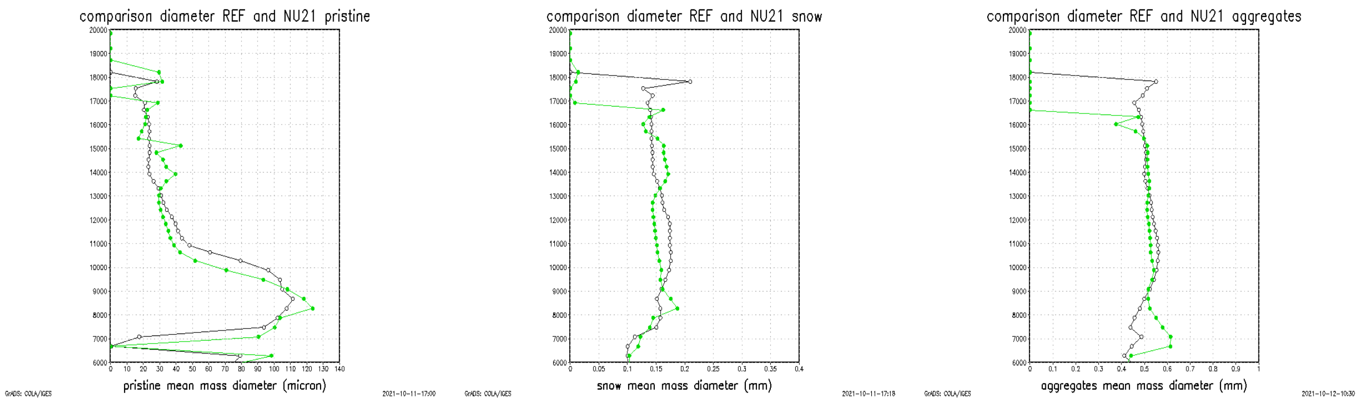
   adjusted - Yes, there are two IOPs in the whole campaign. The paragraph corresponding to line 85 has been changed to eliminate confusion and provide more information about the entire campaign.

   The paragraph begins with: "TRO-Pico is a French initiative based on a small balloon campaign in Bauru (22.36°S, 49.03°W), State of São Paulo, Brazil, and funded by the Agence Nationale de la Recherche (ANR). Its purpose is to study the stratospheric water vapour entry in the tropics at different spatial and time scales. In particular, TRO-Pico main's goal is to better quantify the role of overshooting convection at a local scale in order to better quantify its role at a larger scale with respect to other processes. It took place in March 2012 for the first intensive observation period (IOP) and from November 2012 to March 2013, with regular soundings including a second IOP in January and February 2013. The case under investigation in this paper is part of the first IOP while Behera et al. [2018] investigated the November 2012 to March 2013 TRO-Pico period."

3. ***L.170: The authors should add the main aim to introduce NU21 for the simulation and/or the characteristics of Eq. 1; it would imply the results of L. 389, L. 435, and L. 487-492.***

adjusted - Please see Fig. 1 in the journal of Atmospheric Research by Walko et al. [1995]. On the other hand, the paragraphs corresponding to lines 155–160 and 170 have been revised to include more information on the shape parameter and the objective of carrying out the NU21 simulation. To better assess TTL dynamics, the third simulation, denoted HVR (High Vertical Resolution) hereafter, has a greater vertical grid-point resolution than REF and NU21. Nonetheless, we have attached a figure (#1#) that illustrates a comparison of REF and NU21 mean mass diameter variations in altitude around the overshoots. As expected, the mean mass diameter in NU21 is slightly greater than that in REF, in particular for pristine ice. We recall here that pristine is the first ice hydrometeor to freeze, so that the comparison between REF and NU21 is more straightforward.

The text is now: "Following that, we run three simulations with a spatial resolution of 800 m × 800 m. The first of the three simulations is the reference simulation (REF). The shape parameter (ν) of the hydrometeors in the bulk microphysics setting differs from REF in the second simulation, which is indicated as NU21 (ν = 2.1). NU21 is projected to produce hydrometeors with greater mean mass diameters. To better assess TTL dynamics, the third simulation, denoted HVR (High Vertical Resolution) hereafter, has a greater vertical grid-point resolution than REF and NU21. The impact of NU21's sensitivity to the microphysical component, as well as HVR's vertical resolution, on simulations of deep convection and overshooting plumes, is then examined."



(a) Pristine ice (b) Snow (c) Aggregates

#1# Vertical profiles of mean mass diameters in the vicinity of overshoots for REF and NU21, respectively. The black lines are for REF at 16:15 UT, 22.0°S, 49.18°E. The green lines are for NU21 at 15:45 UT, 22.0°S, 49.2°E (almost the same position but not the same time). Those times correspond to the ones in Fig. 1 of the submitted paper. The positions correspond to the positions of the maximum overshoot in each case.

4. ***L. 226 and Figure 1: The authors should point out "three cells" by arrows in the figure.***

adjusted - Fig. 1 has been updated to include arrows that point to the storm cells.

2 Specific Comments

2.1 Section 6.2 and Figure 8

1. ***The authors should define "the total mass budget" clearly; Was it integrated by time and whole area (1840 km × 1640 km)? The authors should add that liquid was neglected.***

   adjusted - A remark concerning the liquid content has been included to the paragraph corresponding to line 427 of the WV mass budget calculation. It is worth noting that all of the mass budget calculations are limited to the third grid.

   The text is now: "Fig. 8 depicts the total mass budget (kilo tonne, kt) for the five types of ice hydrometeors: pristine ice, snow, aggregates, graupel, and hail, as well as water vapour. It is worth mentioning that the amount of liquid in this calculation has no bearing. The simulations' third grid, which has a domain size of 201 km × 165 km and isentropic values ranging from 380 K to 430 K, is used for time-integrated estimation. Because none of the convective plumes in the simulations exceed this isentropic level, the maximum level is 430 K."

2. ***L. 433: The author should write "kilo tons (kt)" because kt is usually used for "knot". The authors should explain how to calculate 8 kt, which is probably "ice+WV at 17:30" – "ice+WV at 15:00."***

   adjusted - This is exactly how you interpreted it. To avoid any misunderstanding, the mass unit has been explicitly specified in kilotons in line 433, and the text has been revised.

   The text is now: "Our mass budget estimation begins with an unperturbed state (zero total mass), i.e., the time before deep convection begins in each simulation, which is 15:00 UT for REF and 14.00 UT for NU21, respectively, and ends at 17:30 UT for both. This is because the WV time evolution reaches a near plateau profile without including any further overshoots, which would otherwise make the study more difficult. Furthermore, the ice profile (dotted red) is descending, indicating that deep convection activity in the model has ended. Simultaneously, the WV profile (dotted blue) rises and settles around 17:30 UT."

3. ***The authors should explain the legends in Fig. 8. I believe that "17 km < 18 km" denotes of overshoot whose cloud top heights were 17 – 18 km. "intensity" in the caption would be cloud top heights of overshooting tops? The authors should also describe the length of arrows and check "color blindness"; e.g., `https://en.wikipedia.org/wiki/Color_blindness`***

   adjusted - The caption for Fig. 8 has been modified to avoid any confusion. The colours of the arrows were chosen to avoid clashing with the colours of the mass-budget profiles. The smallest arrows (orange) represent cloud top heights of 17 km to 18 km, the middle-sized arrows (green) represent cloud top heights of 18 km to 19 km, and the largest arrows (magenta) represent cloud top heights larger than 19 km.

   The updated caption is now: "Water mass budget (ice and water vapour) for (a) REF and for (b) NU21 in Grid 3 between the 380 K to 430 K isentropic levels. The ice budget contribution includes the five ice hydrometeors (pristine ice + snow + aggregates + graupel +

hail). The colour and length of the arrows indicate the cloud top altitude of each occurrence, with the smallest arrows (brown) referring to cloud top heights of 17 km to 18 km, the intermediate-sized arrows (green) relating to cloud top heights of 18 km to 19 km, and the largest arrows (magenta) corresponding to cloud top heights greater than 19 km."

2.2 Table 1

1. ***Table 1: The authors should describe the method how to count overshoot. For example, I draw three cases of overshooting tops (see the attached); are they one overshoot or two overshoots?***

   adjusted - Thank you for bringing up such an important topic. Our cloud-resolving simulation has a time resolution of 7.5-minute, which is the just same as the volume scanning of the Bauru S-band radar. This time, we ran the expensive simulations with a 30-second time resolution to observe the overshoots and the three scenarios you recommended. The two animations of the overshoots' analysis every 1-minute are included in the reply, which are two latitudinal slices separated by 0.05° across an intense convection area only in the REF run. We can now demonstrate that our estimate of the number of overshoots is neither low nor high. Despite the fact that a lot of dynamics are happening near the 17-km level, we have yet to find any situation that might be considered illustrative of your example case-3. In your example case-1, we always count overshoots as two. We have never observed a circumstance where the overshoots change from case-1 to case-2, as you describe in your second example, case-2. Table.1's caption has also been modified for brevity.

   The updated caption is now:"Count of overshoots above 17 km altitude for the S-Band radar (end time UT of the volume scan) and for the REF, NU21, and HVR simulations. Their counts are represented by multiples of X. Within a 1 km thick layer, the altitude is the lowest point. The modelled overshoots are calculated by taking into account the height of each plume in the 7.5-minute time-lapse imagery, which must be greater than or equal to 17 km, as well as the spatial spread of each plume. Fig. 6 depicts a scenario in which the spatial extent of the overshoot is also taken into account."

References

Sergey M Khaykin, Jean-Pierre Pommereau, Emmanuel D Riviere, Gerhard Held, Felix Ploeger, Melanie Ghysels, Nadir Amarouche, Jean-Paul Vernier, Frank G Wienhold, and Dmitry Ionov. Evidence of horizontal and vertical transport of water in the Southern Hemisphere tropical tropopause layer (TTL) from high-resolution balloon observations. *Atmospheric chemistry and physics*, 16(18):12273–12286, 2016.

Abhinna K Behera, Emmanuel D Rivière, Virginie Marécal, Jean-François Rysman, Claud Chantal, Geneviève Sèze, Nadir Amarouche, Melanie Ghysels, Sergey M Khaykin, Jean-Pierre Pommereau, et al. Modeling the TTL at Continental Scale for a Wet Season: An Evaluation of the BRAMS Mesoscale Model Using TRO-Pico Campaign, and Measurements From Airborne and Spaceborne Sensors. *Journal of Geophysical Research: Atmospheres*, 123(5):2491–2508, 2018.

Robert L Walko, Wr R Cotton, MP Meyers, and JY Harrington. New rams cloud microphysics parameterization part i: the single-moment scheme. *Atmospheric Research*, 38(1):29–62, 1995.