Interactive comment on "The impact of overshooting deep convection on local transport and mixing in the tropical upper troposphere/lower stratosphere (UTLS)" by W. Frey et al.
by Anonymous Referee #2

We'd like to thank the reviewer for his/her comments. Please find a point-to-point reply below, the referee's comments are typeset in bold italic, our replies in normal font.

This study addresses the important question of vertical transport across the tropical tropopause layer (TTL) in tropical deep convection. This is done at the local scale and the authors use a single tropical storm observed on the 30th of November over the Tiwi Islands as a case study for their high resolution model integrations. Overall the model reproduces many of the storm features observed.
Aircraft measurements of O3 and CO are compared to similarly initialised passive tracers in the model simulations and additional idealised tracers are also used to infer upward/downward transport within the convective cloud. The authors have also investigated how changes in water vapour are affected by different processes in the convective system. Overall, the study includes some novel aspects (vertical transport in convective updraft and downdraft) and is clearly structured and well written.

Major point:
The authors should use 'appropriate' scales for the inert tracers plots (Fig 6, Fig7, panels b and d in Fig 8 and 9) and the IWC plots (Fig 5). I think the scale used for plotting a quantity should reflect a significance range interval for the quantity being plotted.
For IWC, convective clouds have a typical IWC of ~1g/m3 at the core while values of 1e-4 g/m3 are generally associated to thin and sub-visible cirrus clouds. The current scale extends to 1e-5 g/m3. Similarly, when looking at inert tracers initialised in a specific layer, the main question the plots are trying to answer is "to which height is a 'significant' fraction of this tracer being transported due to convection?".
Having a scale that extends to very small values is misleading. The current plots show which height an amount of tracers which is respectively 5 (Fig 6, 8, 9) or 15 (Fig 7) orders of magnitude smaller than the initial tracer concentration can be moved by convection. In my opinion, a 'significant' amount of tracer would be 5% to 1% relative to the initial tracer concentration; given the strong vertical gradients of some chemical species around the tropopause an amount as small as 0.1% of the initial concentration might still make a small difference. However, I find it hard to justify plotting anything smaller than 0.1% of the initial tracer concentration (this corresponds to scales down to 1e-3). Plots with smaller scales can be misleading as they show transport of quantities that are so small they are not significant therefore they don't help in trying to explain observed changes in e.g. O3 and CO. It would also help if all scales used for inert tracers were the same (currently plots of the T and A tracers use different scales).
Additionally, sentences in the texts which are currently vague or misleading as a result of the scales used for plotting should be corrected. For example: sentence starting on page 1049, line 27; sentence starting on page 1051, line 26; page 1051, line 6 (note about different scales); page 1053, line 8.

Reply to major points:
IWC:
You are right, that IWCs in the deep convective cloud cores reach those high values. However, as observations have shown, IWCs in the overshoots are much lower. De Reus et al., 2009, Table 1, show that the average IWC (and that means that smaller values are found as well) range between 7.7e-5g/m^3 – 1.3e-3g/m^3. Since these overshoots are major

components of our study, we need to also plot IWCs of down to 1e-5g/m^3 in magnitude. Additionally, the layer of low IWCs below the cold point tropopause is important to understand/explain the simulated dehydration layer in Fig. 13/14.

Tracers:

The first aim of Figure 6 is to show where air masses are transported, to make clear the effect of the convection. Thus, it does not show significant transport, but transport in general.

Figure 7 shows domain averages, where a small amount of tracer might still be meaningful, since the averaging includes large areas where no tracer transport happened. However, these areas affect the value of the average significantly. That is also why the scale changes for the in-cloud tracers, which do not include convectively unaffected areas and accordingly amounts are much higher.

To better guide the reader in context of significance, we decided to add dash-dotted lines in Figure 8 and 9 to show the 1% and 0.1% thresholds.

Minor points:

a)

A previous study using cloud resolving model simulations to investigate vertical convective transport of chemical species (including ozone and CO) has been published in the literature and should be mentioned in the introduction (see Barth et al., Cloud-scale model intercomparison of chemical constituent transport in deep convection, Atmos. Chem. Phys., 7, 4709–4731, 2007)

Reply: We added this publication to the introduction.

b)

Although overshooting convection has been observed (Corti et al. 2008, De Reus et al. 2009) the relative impact of these very localised storms at the global scale has not been fully quantified and could still be negligible if the horizontal extent and overall number of such penetrating storm is small. This should be pointed out and a caveat added in the Introduction (for example following sentence on page 1044, line 13-15).

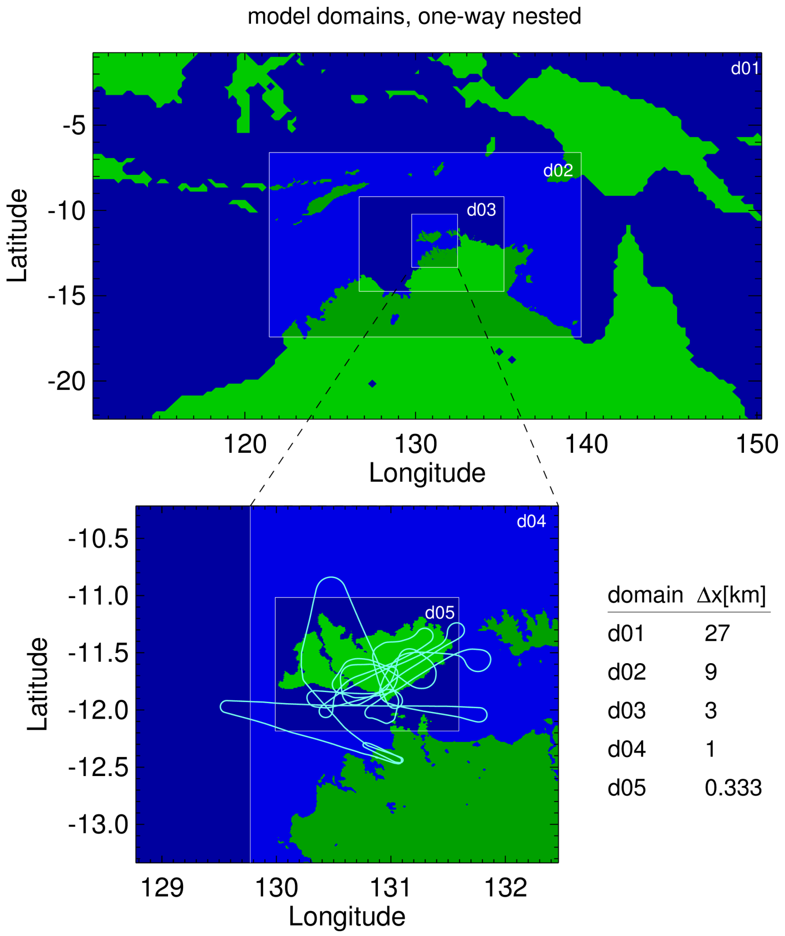
Reply: We added the following text:

“At present it is unclear what the relative impact of these localised storms are on the global scale, though observational campaigns during the early years of this millennium demonstrated a high frequency of overshooting events (Pommereau, 2010), which contrast the generally assumed scarcity of these events. A high resolution climatology of extend and number of overshooting convection events would be needed to fully quantify their impact.”

c)

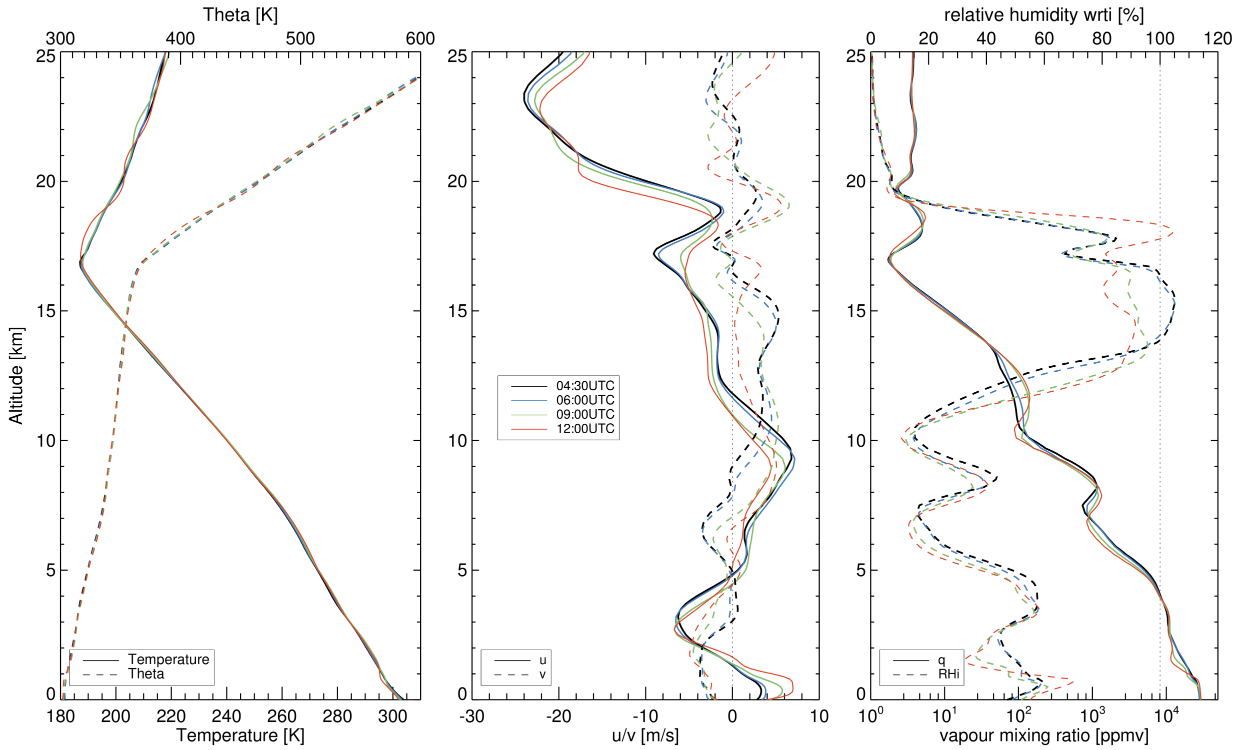
Figure 2: the light blue Geophisica flight track is hardly visible on the green and dark blue background. I suggest using a different colour and thicker line or adding it in a figure inset showing a zoomed-in version of d04. At the moment this confuses the picture without adding much extra information.

Reply: We changed the figure according to your comment, please find the new version below:



d)
Figure 3: it would be useful to add extra panels, or extra lines in the existing panels, or an extra figure to compare these quantities (shown prior to Hector) with the same during and after Hector (say at 6 and 12UTC). In particular, the height of the tropopause (panel a) is critical to address the extent of modelled cross-tropopause transport and at the moment it is not clear how this changes in response to convection in the model.

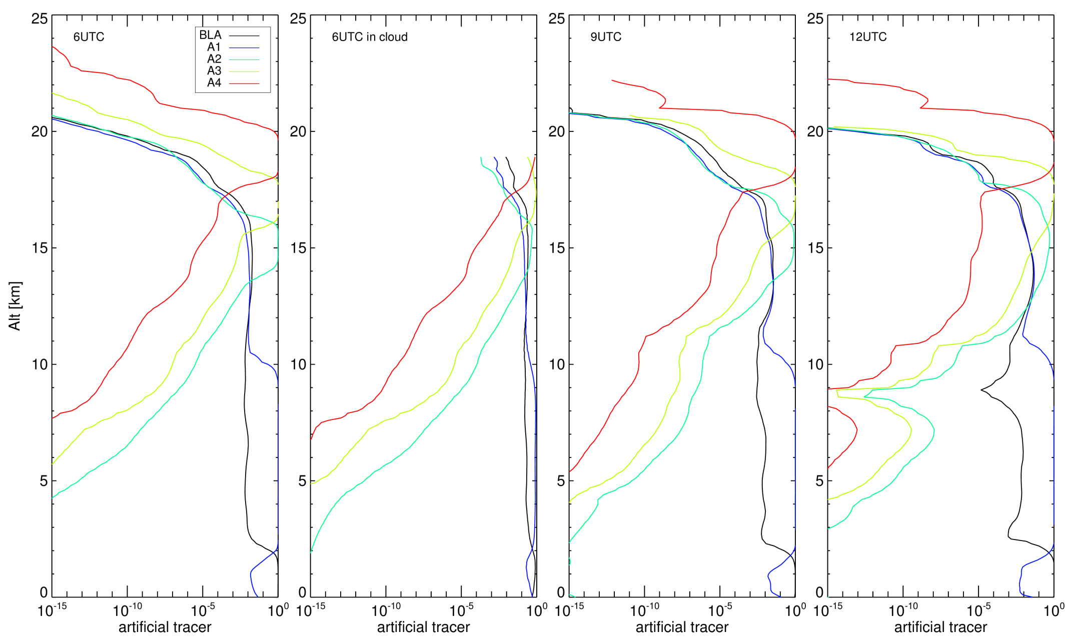
Reply: Find the figure with new times (6, 9, 12UTC) included below. As you can see, there are no substantial changes in the temperature profiles. Therefore, we think it could be sufficient to mention this in the text but not to plot in the Figure, to avoid cluttering and confusing the figure too much. Furthermore, the cold point tropopause is shown in Figure 5 and 6 as dotted line. We added the following at the beginning of Section 4: “The height of the simulated cold point tropopause changes to 16.8km/16.8km/17.1km at 06:00UTC/09:00UTC/12:00UTC.”



e)

Figure 6: it would be beneficial to add an extra column for 9UTC. This would be more consistent with Figure 10 and also illustrate the point made in the text about BLA, A1 and A2 reaching highest at 9UTC (page 1051, line 21-22).

Reply: We added a column with cross sections for 9UTC into Figure 6. The point about tracers reaching higher into the stratosphere was based on the following profiles, where small amounts reach up to 21km. As mentioned in the reply to your major comment, in a domain average a small amount might still be meaningful, since the averaging includes large areas where no tracer transport happened, but these areas affect the value of the average significantly. That is also why the scale changes for the in-cloud tracers, where amounts are much higher.



To address your comment about scales we changed the text accordingly: “ Small amounts of BLA, A1, and A2 even reach up to about 21 km at 09:00UTC and fall back to 20km at 12:00UTC (at scales smaller than plotted here).”

f)

Fig 15: at the moment it appears that two different figures are labelled as Fig 15 (one with no caption). This should be corrected.

Reply: These two figures are indeed one figure, we just decided to split them for better visibility in the ACPD format. The captions were typeset according to the ACPD rules (discussed with the typesetter). However, in a final revised version this figure will be put together as one again.

References:

de Reus, M., Borrmann, S., Bansemer, A., Heymsfield, A. J., Weigel, R., Schiller, C., Mitev, V., Frey, W., Kunkel, D., Kürten, A., Curtius, J., Sitnikov, N. M., Ulanovsky, A., and Ravegnani, F.: Evidence for ice particles in the tropical stratosphere from in-situ measurements, *Atmos. Chem. Phys.*, 9, 6775–6792, doi:10.5194/acp-9-6775-2009, 2009.

Pommereau, J. P.: Troposphere-to-stratosphere transport in the tropics, *CR Geosci.*, 342, 331–338, doi:10.1016/j.crte.2009.10.015, 2010.