Reply to referee George Craig

The authors appreciate the valuable comments on the manuscript which led to a significant improvement. Referee comments are given in bold, the answers in standard font. Changes to the text are in italics.

Generally, we note that we revised most of the figures based on suggestions from the three referees. We also changed some of the acronyms of our experiments. Moreover, we included three more figures (new Figures 9, 15, and 16 in the revised manuscript) and based on questions and comments from Sebastian Schemm and George Craig we included a new section (Section 5 in the revised manuscript) in which results from LC2 experiments are discussed.

Answers to specific comments

In particular whether different vertical ascent patterns in an LC2 case would give different sensitivities, and what would happen in complex developments involving multiple and secondary cyclones which contribute to the global TIL.

Following this comment and a comment by S. Schemm we added a new section on the TIL in LC2 experiments (new Section 5). However, the overall conclusion stay the same, since the results from the LC2 experiments further support those results already presented in the manuscript for LC1. However, the role of gravity waves is discussed a bit more in detail in this context.
The evolution of the TIL in complex situation, especially regarding the maintenance of enhanced static stability as a product of multiple processes is for sure a question of interest and will be addressed in a consecutive study. However, since such analyses require a new design of the experiments, they are beyond the scope of the current study.

l.277. Could you give a definition or reference to the definition of "thermal tropopause". There are so many versions around that I would like to be sure I have the right one.
We follow the definition given in WMO, 1957. The thermal tropopause is defined as the lowest level where the temperature lapse rate falls below 2 K/km and its average between this level and all higher levels within two km above this level remains below this value. We added the description and the reference to the manuscript in Section 2.

l.299-300. The metric for spatial extent of the TIL involves arbitrary thresholds. Has this been used in previous work, and is there a reference that looks at sensitivity to the choices of parameters?
To our knowledge this metric has not been used in other studies. We wanted to have a further metric for the spatial extent of the TIL and not only one for the maximum values. We have chosen the threshold such that it is significantly larger

than the initial maximum value of N^2 in the lower stratosphere. We also tested other (larger) threshold values which showed qualitatively the same results. We added this information to the manuscript.

l.332#. I found this discussion confusing. Comparing Fig. 2 (a) and (d), it looks like the main difference is located at the southern end of the trough, rather than in the WCB outflow as in some of the later experiments, which one would guess would be more related to convection (resolved vertical ascent since the parameterization is not used) than slantwise ascent. The Gutowski reference would be more useful if there was a brief mention of what he said about the two processes.

Figure 2 shows the distributions of N^2 after 120 h. The new Figure 9 in the revised manuscript shows the distribution of static stability N^2 as well as contour lines of the column integrated cloud ice content for the times between 78h and 138h in 6 hourly intervals for BMP. After its first appearance large values of static stability do not only stay directly above the center of the WCB but are also evident in a region south east of the WCB outflow that moves away from the WCB center. In this region the static stability values stay large, although the forcing from below is not evident anymore. As far as we can analyze it is related to an interaction with gravity waves that are present in this region (see also Kunkel et al., 2014). We hope that this new Figure helps to reduce the confusion resulting from Figure 2.

Gutowski et al. (1992) conducted dry and moist baroclinic life cycle experiments. Their analysis showed that the largest effects of condensation are associated with increased vertical transport and that the moist life cycle evolves faster than the dry one due to an increased energy conversion due to stronger vertical motions. We rephrased the according sentence to:
"Our results agree with those obtained by Gutowski et al. (1992). They compared dry and moist baroclinic life cycles and showed that including moisture leads to stronger updrafts as well as to a faster evolution of the life cycle.

Fig.10,13. Why are these not plotted at 120 hrs? I would have liked to compare with Fig.8 (and maybe 12).

Both figures could be plotted at 120 hours and 144 hours, since there is no big difference with respect to the physical interpretation that we wanted to make at this point. Nevertheless, to obtain a better comparability with Figure 8 and 12 we change Fig. 10 and show the same cross sections at 120 hours (new Figure 11 in the revised manuscript). To reduce the redundancy we keep showing Fig. 13 at 144 hrs. For completeness we show Fig. 13 also at 120 hours here (Figure A).

l.565ff. Is it possible to summarize in a couple of sentences what the effect of gravity waves is, or is it sufficiently complex or random that one must read the entire paper?

Gravity waves, in particular inertia-gravity waves (IGWs) with a relatively slow speed of propagation and quasi-horizontal direction of propagation, can potentially break in the region above the tropopause. This is the case, if they modify the background such that Kelvin Helmholtz instability develops which is a sufficient criterion for IGWs to break. Breaking gravity waves can lead to energy transfer to smaller scales as well as to the generation of turbulence. Both the energy transfer and turbulence have impacts on the stratification but are not yet fully quantified. This has been discussed in Kunkel et al. (2014) using model simulations and linear instability theory. Otsuka et al. (2014) and Zhang et al. (2015) also presented analyses that link gravity waves with the tropopause inversion layer.

Typos:
title: ...life cycle experiments...
Corrected.
l.293. spontaneously -> suddenly
Corrected.
l.296 than -> then
Changed to: *"Only after about 130 h after model start N2max in RAD, and a little bit later in REF and TURB, has reached the same magnitude as in the moist simulation."*
l.511. tenth -> tenths
Changed as suggested.
l.523-525. Sentence fragment
Changed to: *"A life cycle experiment with only dry dynamics served as reference case, while three additional life cycle experiments have been performed with individual non-conservative process added. "*

References:
Gutowski, W. J., Branscome, L. E., and Stewart, D. A.: Life cycles of moist baroclinic eddies, J. Atmos. Sci., 49, 306–319, doi:10.1175/1520-0469(1992)049 <0306:LCOMBE>2.0.CO;2, 1992.

Kunkel, D., Hoor, P., and Wirth, V.: Can inertia-gravity waves persistently alter the tropopause inversion layer?, Geophys. Res. Lett., 41, 7822–7829, doi:10.1002/2014GL061970, 2014.

Otsuka, S., Takeshita, M., and Yoden, S.: A numerical experiment on the formation of the tropopause inversion layer associated with an explosive cyclogenesis: possible role of gravity waves, Progress in Earth and Planetary Science, 1, 19, doi:10.1186/s40645-014-0019-0, 2014.

WMO, Meteorology-a three dimensional science, WMO Bulletin, pp. 134-138, 1957

Zhang, Y. et al.: The Interaction between the Tropopause Inversion Layer and the Inertial Gravity Wave activities revealed by radiosonde observations at a midlatitude station, J. Geophys. Res. , doi: 10.1002/2015JD023115, 2015.

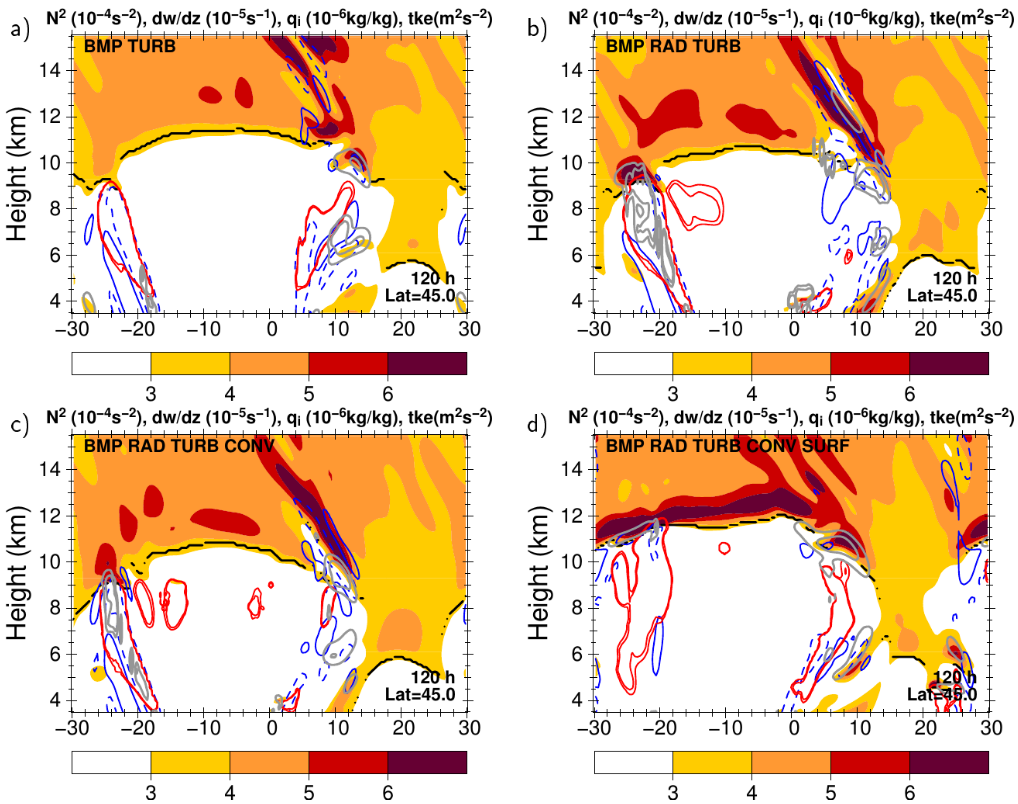

Figure A: As Figure 13 in the manuscript but at 120 h after model start.