Review of “Impact of cirrus on extratropical tropopause structure” by Nicolas Emig, Annette Miltenberger, Peter Hoor and Andreas Petzold

The paper describes in detail the observation and formation of a cirrus cloud in the extra-tropical transition layer (ExTL) over the North Sea by means of observations that have been taken during the AIRTOSS-ICE campaign and high-resolution ICON simulations including calculation of online trajectories. The combination of the observational data and the high-resolution model simulations enables to investigate in detail the formation of the cirrus cloud and its impact on the ExTL structure. Thereby, the model performance in simulating this case is discussed and the impact of diabatic processes on the modification of the temperature and potential vorticity profile in the ExTL is determined based on temperature-tendency output from the model simulation. The methods that are presented are appropriate and the study provides new insights in how cirrus clouds can influence the ExTL. The paper is therefore suitable for publication after minor revisions.

General comments:

The paper is generally well written, and the main findings are supported by the figures. However, some of the figures and the associated text need some clarification. Please also read carefully all your figure captions because in several figures they are not complete, and some necessary description is missing.
For more details see my comments below.

Abstract: I would remove the sentence “Earlier analysis by Müller et al. (2015)” here and instead emphasize that you present a combination of measurements and a high-resolution simulation including a Lagrangian analysis. Therefore, I would slightly reformulate the first paragraph of the abstract to something like:

Here we present for the first time a combination of in situ observations of the ExTL thermodynamic structure in- and outside cirrus by utilizing a dual-platform approach and a Lagrangian analysis based on high-resolution simulations. The observational data were collected during the AIRTOSS-ICE campaign.
The dual-platform approach reveals substantial disturbances in the vertical profile of potential temperature with a weakened stratification inside the cirrus and sharpening above. …

L 34: …isentropic composition gradients indicate the effect of irreversible transport …. Why is this the case? Can you briefly explain?

L 121 and 124: ICH-Sensors → MCH-sensors …?

Fig. 1: “colour bar”; to what exactly do you refer to here with LOW and HIGH?

L164: …form in the the humid -> delete “the”

L172/173 → …. **dark** grey for the TOSS-platform and light grey ….

L175 and Figure 2: could you please indicate in Figure 2 on which section you focus?

Figure 2: the figure does not provide important information; I find the information given in Figure 3 much easier to understand and more important. I would either remove Figure 2 or maybe show additionally a map below the flight pattern such that it becomes clear where the Learjet is flying, also to be able to compare it to the satellite images.

Figure 3 a, theta gradient: wouldn’t it be more interesting/intuitive to see the difference in theta values between the Learjet and Toss measurements, because you also state that the vertical distance deltaz between Toss and Learjet was constant (thus, K/deltaz), instead of showing a gradient in units of K/km? A gradient of 25 K is huge and doesn’t tell us anything about the stratification in the considered layer? Or do I misunderstand something here? Thanks for clarifying.

L 200: …6.6 °° E → 6.6 °E

L 200: One of the two mixing lines showing …. → which one? What does the other show?

L 200 – 207: I have difficulties to follow your description of Figure 4. Can you describe in more detail what exactly the two different mixing lines you are referring to are? You also say that RHi reaches 100% inside the cirrus layer? However, the values inside cirrus are already blue, so supersaturated? Thanks for clarifying.

Fig. 5 d: x-axis, insert missing bracket

L 241: Over the analysed 2 h time window…. Shift this sentence to line 235, thus to description of figure 5.

Figure 6: missing bracket in x-axis description of panel b); figure caption last words: …and no clouds (red) being present. In general, you could think about different colours for the red and green lines due to colour blindness.

L 242-249: you may want to shift the description of figure 5d to line 236 before you start the discussion of figure 6.

L 258: to investigate these processes we analyse…

Figure 7: what are the vertical dashed lines? Why do the trajectories extend beyond the target region? Improve colour scale for panels a, d and g, because most of the values are in the green colour range.

L 293: histograms in Fig. 8a

L 300-301: considering the parcel's initial PV …. What exactly do you mean here? Why is it important here and what does it tell us?

Section 4.3: This section, including Figure 9 contains interesting and important information. However, the explanation in the text and the link to the figures are sometimes not easy to follow. So please make sure that all lines, hatching, dots, …. are explained in the figure caption of Figure 9 and refer to the plots in the text (including, white solid/dashed line, grey circles, dots, red hatched area, green solid line). For example, it would be very helpful to have the 2 pvu and 6 pvu isolines in each panel (are the white lines in panel b the pv isolines?). In panel b I would also improve the colour of the PV values. Now it is not easy to see the values precisely, one can only estimate the value at a given point.

L 360: 8,7 → 8.7

L 365: …more tenuous cirrus further east (Fig. 10c). I have difficulties to see where the tenuous cirrus are, how they appear in panels c, f, i. Some more explanation would help.

L 389: You state that the moist layer is not as sharply capped in the model as in the observations. However, I cannot see this in the lines in Fig. 11b.

Figure 11: I would use the same colours for the triangles indicating the radiosonde stations and the lines in panel b). For example, the triangle for Oberschleissheim should be yellow. I would also either remove the WCB outflow, because this is not mentioned in the text describing Figure 11 or add the text mentioning the importance of the WCB outflow that is in the summary (L492) also here.

L420: …a negative PV anomaly develops. Is it really a negative PV anomaly or is just the difference negative? In general, it is difficult to relate the text to the figure. Can you please improve this and point more precisely to the regions you are referring to.

L429: …., which is characterised by

L459: I don't understand what you mean here with "making substantial STE during the transit unlikely". Where does this conclusion come from?