Using a perturbed parameter ensemble (PPE), this interesting study investigates how microphysical uncertainties affect water transport and cirrus properties in a warm conveyor belt (WCB) case. While thermodynamic conditions at the end of ascent are largely insensitive to parameter changes, ice content and relative humidity show strong variability, primarily controlled by ice crystal capacitance (CAP) and ice-nucleating particle (INP) scaling. These sensitivities are especially pronounced in fast-ascending parcels, where modifications to the saturation adjustment scheme further affect cloud properties.

Overall, the manuscript is logically structured, clearly written, and suited for publication in ACP. I recommend acceptance after minor revision. My specific comments and questions are outlined below, followed by a few technical remarks and suggestions for improvement.

Major Comments

- In Oertel et al. (2025), and in this paper, a multidimensional Gaussian Process (GP) emulator is used to approximate model behavior. This approach assumes that input parameters, such as capacitance, vary smoothly and that the resulting model output — including variables like ice number concentration and mean ice particle size — responds in a continuous and predictable way.

  Although internal nonlinearities exist in the Seifert and Beheng (SB, 2006) microphysics scheme (e.g., mass–size relationships, category transitions), these are embedded within the model physics and do not necessarily introduce discontinuities in the macroscopic output variables if each hydrometeor category is analyzed separately.

  However, imposed minimum or maximum limits on ice number concentration may lead to plateaus or discontinuities in mean ice size, particularly when ice mass continues to grow while the number concentration is constrained. Additionally, ICON's saturation adjustment scheme limits supersaturation to 100% in regions containing cloud droplets or rain, potentially producing flat regions in the relative humidity w.r.t. water output fields. Given that a Gaussian Process emulator is applied, do these plateaus or discontinuities introduce challenges (if they exist in any of the output fields) for the emulator's ability to accurately capture the underlying parameter–response relationships?

- In these ascending parcels considered within the WCB, the updraft speed is not zero. For example, when $w = 0$ and $N_i r_i = 10^{-1}\,\mu\mathrm{m}\,\mathrm{cm}^{-3}$, the relaxation time can be as large as $10^4\,\mathrm{s}$ (Fig. 1). If $w = 1\,\mathrm{m/s}$, the relaxation time can be reduced by approximately an order of magnitude under upper tropospheric conditions. For larger values of $N_i r_i > 10^1\,\mu\mathrm{m}\,\mathrm{cm}^{-3}$, the impact of $w \leq 1\,\mathrm{m/s}$ becomes negligible (e.g., Korolev and Mazin (2003)).

  Assuming $w = 0$ for all analyses of ascending parcels may lead to severely overestimated the ice phase relaxation times, particularly for fast-ascending trajectories.

It is stated in Line 492 that $w \approx 0$ for parcels taken at the end of ascent, but later, for example in Section 4, fast ascending trajectories are analyzed together with relaxation timescales. It is therefore recommended to explicitly include w in the relaxation timescale formulation to make this analysis more robust.

- Line 430: "The mean maximum mixing ratio for snow (max(qs)) during ascent also increases with CCN (Fig. 5 e), presumably because in the two-moment microphysics scheme riming contributes to the mass growth rate of snow,...". The reasoning here may not agree with how riming affects particles in SB. In this case: When riming occurs it can have a two fold effect on ice and snow. If ice or snow rimes with raindrops it is converted to graupel else if it rimes with cloud droplets it remains either ice or snow unless it exceeds a critical rime mass threshold depending on some tuning parameter. Typically snow is considered as pristine and therefore is converted quite rapidly to graupel (by assuming a low space filling constant). If riming on snow occured more often then qs would most likely decrease because of this conversion, not increase, right?

  I would suggest the process look more like the following: Increased CCN concentrations lead to more numerous but smaller cloud droplets, which slow the formation of raindrops. This, in turn, reduces the collision efficiency between ice or snow particles and cloud droplets, slowing the conversion to graupel. As a result, snow remains more abundant.

- Line 394: I follow this reasoning, but a similar reasoning can be applied to lower INP scaling: with fewer activated INPs, there is less competition for available vapor, resulting in larger mean ri. This in turn enhances the conversion from qi to qs through enhanced collisions with raindrops and ice particles. Some aspects of this or the authors reasoning may become clearer, and confirming the authors explanation, when qs is also plotted in reference to Fig. 4d, e, and f.

Minor Comments

- Line 27: Instrument uncertainties remain, with calibrated measurements typically accurate to within 5–10% in supersaturated regimes (Petzold et al., 2020). Can it be added to highlight uncertainty with instruments.
- Line 42: "tropopause region has increased on average from 2011 to 2020 compared to the 1980s". Can a more specific value be added?
- Line 48: "key contributor to extratropical UTLS moisture". By how much do WCBs contribute?
- Line 59: "various atmospheric constituents". Be more specific and replace the phrase with ...water vapor, hydrometeors and aerosols...
- Line 64: What is meant by the "incorrect representation of WBCs"? What is misrepresented? The location, vertical extent, cloud dynamics, cloud microphysics or water vapor transport?
- Line 70: Cloud overlap can also change a cooling effect into a warming effect during the day (Johansson et al., 2019).

- Line 73: Is the warming effect the average when considering day (cooling) and night (warming)?
- Line 105: "Supersaturation" is a continuous variable. Change the sentence to: "otherwise, greater or more widespread supersaturation would be produced."
- Line 118: If the cloud is glaciated then CCN becomes less relevant because of the Wegener-Findheisen-Process. In this case would CCN matter? Before glaciation CCN may be very important.
- Line 165: I realize that is given in previous papers, but it would be good to have a very short one paragraph overview here with Figure 1 from Oertel et al. (2025).
- Line 219: Replace the sentence with "In the PPE, the scheme is modified to allow supersaturation to develop under conditions of strong vertical velocity."
- Line 394: I follow this reasoning, but a similar argument applies to lower INP scaling: with fewer activated INPs, there is less competition for available vapor, resulting in larger mean ri. This in turn enhances the conversion from qi to qs. Some aspects of this reasoning might become clearer, and confirming the authors explanation, when qs is also plotted in reference to Fig. 4d, e, and f.
- Figure 3 caption: Keep the caption between Fig 3 and 4 consistent... is it median qi, median Ni median ri or only qi, Ni, ri? I believe it should Fig. 4's description is incorrect.
- Line 444: I don't fully understand this hypothesis. Could you please provide one or two additional clarifying sentences? Does it suggest that stronger convection over higher SSTs would lead to increased Ni and qi? If so, it seems that the primary driver would not be the SST itself, but rather the associated increase in vertical motion.
- Line 548: Issue with brackets.
- Line 551: It is a interesting idea. Can you plot the cloud droplets numbers concentration in each case just before the homogeneous freezing temperature? E.g. are there more cloud droplets available for CAP < 0.4 and INP scaling < 0.5? If so, this will solidify your reasoning.
- Line 559: Issue with brackets.
- Line 593: Ice hydrometeors sublimate. "...(or evaporate/sublimate in case of...".
- Line 508: If one further assumes that the parcel is subsaturated, or that collisional growth is negligible and no conversion to snow occurs under supersaturated conditions, right?
- Table 3. Keep the caption consistent with Table 2 where you can.
- Figure 15 and others. Consistency. Sometimes a) is used or (a)

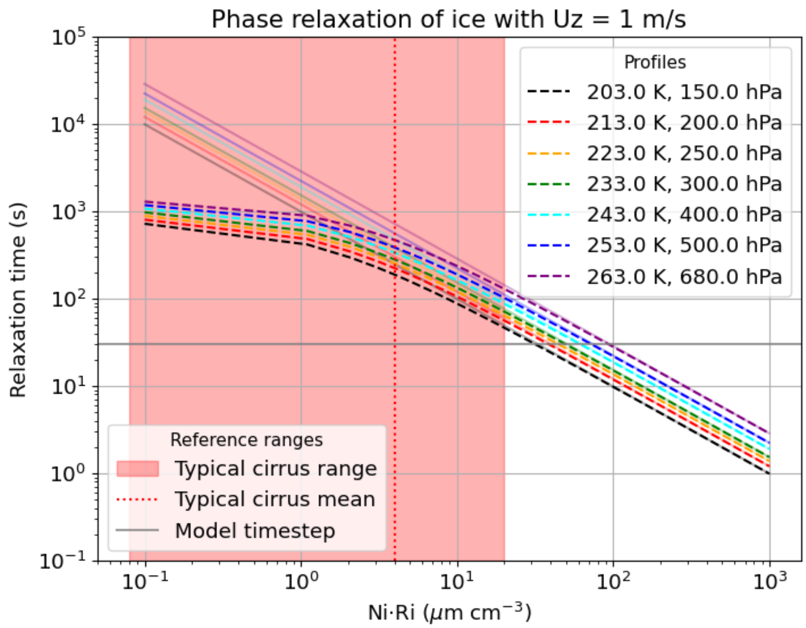

Figure 1. Phase relaxation timescale dependence on updraft speed and Ni*Ri. Solid lines are for an updraft speed (Uz) = 0 m/s and the dashed lines are for the corresponding Uz of 1 m/s. The figure follows the equations from Korolev and Mazin (2003) and extent it to different atmospheric conditions.

- Line 629: Define (RQ) above where Research Question is mentioned.
- Line 634: Consistency with using tau or τ.
- Line 692: How would one constrain realistic values for CAP if it is a function of the habit of ice crystals which keeps changing depending on the state of the environment?
- Line 693: "Keeo". Keep
- Line 698: "scaling factor 5 h after".
- Line 704: In the intoduction Earth's Radiation budget is mentioned and the sensitivity to vapor content in the UTLS. How does the results presented here have an impact radiation.

References

Johansson, E., Devasthale, A., Ekman, A. M. L., Tjernström, M., and L'Ecuyer, T.: How Does Cloud Overlap Affect the Radiative Heating in the Tropical Upper Troposphere/Lower Stratosphere?, Geophysical Research Letters, 46, 5623–5631, https://doi.org/10.1029/2019GL082602, _eprint: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2019GL082602, 2019.

Korolev, A. V. and Mazin, I. P.: Supersaturation of Water Vapor in Clouds, Journal of the Atmospheric Sciences, 60, 2957–2974, https://doi.org/10.1175/1520-0469(2003)060<2957:SOWVIC>2.0.CO;2, 2003.

Petzold, A., Neis, P., Rütimann, M., Rohs, S., Berkes, F., Smit, H. G. J., Krämer, M., Spelten, N., Spichtinger, P., Nédélec, P., and Wahner, A.: Ice-supersaturated air masses in the northern mid-latitudes from regular in situ observations by passenger aircraft: vertical distribution, seasonality and tropospheric fingerprint, Atmospheric Chemistry and Physics, 20, 8157–8179, https://doi.org/10.5194/acp-20-8157-2020, publisher: Copernicus GmbH, 2020.

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