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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Impact of gravity waves on the motion and distribution of atmospheric ice particles" *by* Aurélien Podglajen et al.

**Anonymous Referee #1**

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## General remarks

This investigation points to an effect in cirrus clouds that has so far been largely overlooked, called wave-driven localization. It means that by the combined action of waves, crystal sedimentation and crystal growth/sublimation it can happen that crystals collect in a region where the relative humidity wrt ice is about 100%. The important consequence of this is that the lifetime of those crystals is longer than without the waves since the crystals cannot fall away from that "elliptic fixed point"; this in turn might reduce dehydration and increase the occurrence of thin cirrus in the TTL.

This is an interesting paper, with a high quality of its mathematical derivations and numerical applications. It is worth publication in ACP.



That said, I must admit that I am not convinced of the relevance of the localization effect for the atmosphere. This remains to be demonstrated. There are two major reasons for my scepticism:

## Major points

1) There are a number of simplifications, necessarily in the analytical model, and in the numerical model. For many of these there may be good reasons or they are harmless (spherical crystals). But there are two simplifications that may be critical.

One is the assumption that crystals are already there at the initialisation of the model. On page 18 the authors state " What happens ... is that only the ice crystals INITIALLY located near $RH_i \approx 100\%$ remain ...". As ice nucleation usually needs high supersaturation, I wonder whether there are ever ice crystals initially at 100%.

The other critical assumption is that of a negligible feedback of crystal growth/sublimation on RHi. As the authors say, high crystal concentrations are common in TTL cirrus, so that assumption might be unrealistic. To my view, it is an assumption that might be necessary to develop the theory and the arguments, but later it could be relaxed. It should be relatively easy to run the numerical model with water-ice feedback. The question then is whether the localization effect is still present when the feedback is switched on.

However, actually there are cirrus clouds in the TTL that have extremely small crystal number concentration. These are the "Ultrathin Tropical Tropopause Clouds (UTTCs)" (Peter et al., 2003). Luo et al.(2003) have proposed a mechanism that leads to a stabilisation of such clouds. I suggest that the authors mention the UTTCs and the corresponding mechanism, although it works without waves. Also Spichtinger and Krämer (2013) proposed a mechanism that would produce clouds with low crystal numer densities; their mechanisms works with short waves where the wave "down phase" es-

sentially terminates the ongoing nucleation process. I think this work should also be mentioned and the difference between the proposed mechanisms briefly discussed.

2) On page 20 (last lines) the authors make the point that the localization is an important effect and that its disregard in global models with their course vertical resolution and in weather models leads to "significant uncertainties". To my view, this is too cheap a statement. The statement may be ok if it had been written in conditional tense and without the "significant". Otherwise, it must be shown what the bad consequences of its negligence are on dehydration, radiation, water vapor transport into the tropical stratosphere, etc.

## 1 Minor points

1) Page 2, Line 21/22: As the wave phase is a purely mathematical object, I suppose that it can only affect ice crystals indirectly. An influence can only be exerted by material (physical) properties of the crystals environment, as T or RH. Does your statement imply that such properties are uniquely related to the wave phase?

2) P. 3, L. 2: Is it possible at all that RH=const in a wavy environment? Perhaps in this special case you better speak of "solid particles that fall but that don't grow or sublimate" instead of ice.

## 2 Tiny points

1) Page 1, Line 22/23: Isn't the wind identical to the movement of air parcels?

2) P. 2, L. 2: 190 K is not a range.

3) P. 2, L. 3: insert "of the" before "atmosphere".



4) P. 2, L. 15: write "to and fro" instead of "to and from".

5) P. 2, L. 20/21: "the falling particles fall in the same direction as the wave phase" implies that the phase falls. Better write "the falling particles fall in the direction of wave propagation".

6) P. 2, L. 32: which system?

7) P. 5, L. 3,4: "green" should be "red".

8) P. 5, L. 26: Although the notion "perfect gas" exists (a further simplification of an ideal gas), the gas constant should be termed "gas constant" or "specific gas constant for water vapor". There is nothing in the calculation presented that needs the assumptions of a "perfect gas".

9) P. 7, L. 5: please write "crystal number concentrations".

10) P. 7, L. 27: The "next section" is 2.2.3, not 2.2.1.

11) Eq. 18: I am puzzled by the terms $RH_{i_c}(\overline{Z})$. Before $RH_{i_c}$ was introduced as a constant. Why is it now a function of $\overline{Z}$? Please mention also the meaning of the terms in the brackets (probably Clausius-Clapeyron and pressure change?).

12) P. 8, L. 17: As $RH_{i_c}$ was never specified, is the fix point possible for the whole range of possible values? Is it tacitly to be understood that $RH_{i_c}$ is close to or above ice saturation since there are ice crystals?

13) P. 9, L. 3: Check sentence!

14) P. 9, L. 13: Which of the amplitudes?

15) Fig. 2: Is it possible to indicate the direction of the motion in phase space?

16) P. 11, L. 11-12: On first reading, it was not clear to me what exactly is the difference between the "cold" phase in the eastern Pacific and the "cooling" phase in the western Pacific. Only the later reference to figure 2 clarifies that. I suggest to refer earlier to the

figure to illustrate the distinction.

17) Figure 4 does not show green points, contrary to what the caption says.

18) P. 14, L. 17: blue is a color as well!

19) P. 16, last par: change "equality" to "equation".

20) Figure 6: blue and black are hard to distinguish.

21) P. 18, L. 15: The sentence is a bit strange. In clear sky there are no cirrus clouds. How can then their dehydration efficiency be constrained?

22) P. 19, L. 6: "order" should be "power".

23) P. 19, L 30.: "disagreement" between what?

References

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