Atmos. Chem. Phys. Discuss., 15, C2879–C2885, 2015
www.atmos-chem-phys-discuss.net/15/C2879/2015/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The role of ice nuclei recycling in the maintenance of cloud ice in Arctic mixed-phase stratocumulus" *by* A. Solomon et al.

Anonymous Referee #1

Received and published: 23 May 2015

article geometry

margin=1in

Review of **The role of ice nuclei recycling in the maintenance of cloud ice in Arctic mixed-phase stratocumulus**
A. Solomon, G. Feingold, and M. D. Shupe

acp-2015-177

May 22, 2015

1 General Comments

This study investigates the persistence and liquid-ice phase partitioning of mixed-phase stratocumulus clouds typical of the Arctic. The authors suggest that subcloud ice crystal sublimation produces ice nuclei that recycle back into the cloud layer to reactivate ice particles. The recycling of ice nuclei act to maintain the ice water content over a longer time-scale than without recycling, and with the combination of cloud-top radiative cooling, both liquid and ice contents can be steadily maintained. The authors also imply a diurnal impact on the maintenance of mixed-phase stratocumulus in that both liquid and ice productions are weakened in the presence of shortwave radiation, which in turn reduces ice precipitation fluxes out of the layer, and hence further prolonging the lifetime of the system.

Previous studies on the maintenance of mixed-phase stratocumuli involve the discussion of the rapid glaciation and dissipation of these clouds due to efficient ice depositional growth via the evaporation of the liquid content, usually at higher ice concentrations. Because ice nuclei recycling effectively maintains a consistent ice concentration, it would be curious to see what role recycling would play in liquid/cloud dissipation rates. Furthermore, figures 7a and 10a indicate that, over time, the liquid water content achieves higher values when the diurnal cycle is consistent, in contrast to the ice water content, which drops to lower values. This result is not discussed, but one would imagine that the diurnal cycle would also help to maintain a mixed-phase cloud that would otherwise dissipate.

The work presented is very interesting and compelling. The recycling technique appears to compare well with previous work that employ relaxation ice concentration methods for simpler studies, and so perhaps the recycling effect could

be considered a motivation for simulations with assumed constant ice concentrations. The manuscript is well written, concise, and organized thoughtfully. The manuscript content and figures, however, are very compact and complex, so I would urge the authors to consider simplifying and/or shortening sentences throughout for ease of reading. I would also encourage the authors to simplify figures so that they are easier to interpret.

With the advice given above and the suggestions listed below, my recommendation for this manuscript is *accept for publication with major revisions*.

2 Specific Comments

1. Page 11729, Lines 4-7, "However, unlike subtropical...at cloud top": Which process are considered to dissipate subtropical mixed-phase clouds that do not occur in the Arctic? One would imagine that subtropical clouds could also be supplied with moist air at cloud top. Are AMPS unique from all other mixed-phase stratocumuli in other regions (e.g., midlatitudes)? If so, is there a specific quality (e.g., temperature, solar zenith) in AMPS to contribute to these differences?

2. Page 11730, Line 22, "We posit that recycling...": The term "recycling" has been used many times thus far, but has never been defined or conceptually explained.

3. Page 11730, Line 27, "...while AMPS...": Perhaps change to "...while persistent AMPS". AMPS are not necessarily always persistent, so please be sure to differentiate throughout.

4. Page 11731, Line 2: Please indicate whether recycling is turned off or on for the Control simulation as it is never indicated.

5. Page 11735, Line 2: Are the IN that are produced via sublimation always recycled back into the layer? Is it possible that some IN become "inactive" after sublimation?

6. Page 11735, Lines 8-13: Interpretation of figure 2 is unclear. Do you only consider activation at these threshold temperatures, or would a concentration of 1.3-1.5/L nucleate at -20° versus 0.75/L at -15°? What is unique about these temperatures that make them "threshold"?

7. Page 11735, Line 22: What is the importance of the "modification of activation thresholds" and why is this consideration unnecessary for this work?

8. Page 11736, Lines 13-14: "Crystal size...Fig. 5": Why would the maximum ice size (5 mm) be larger than the maximum snow size (0.7 mm) in Figure 5? What are the shape or aspect ratios and densities considered for snow and ice? What are the physical processes considered for snow and ice?

9. Page 11736, Line 24: To interpret figure 6, it would help to mention that IN are "lost" to activation of ice crystals.

10. Page 11737, Lines 15-23, "Over the...subcloud layer": If the cloud was coupled, could you expect different results since rather than the turbulent eddies sweeping the IN back into the cloud, the IN could sediment to lower levels and not be recycled.

11. Page 11737, Lines 23-25, "The continuous...mixed-layer base." This statement is unclear. Is this statement suggesting a "residence time" effect in that IN are advected into the cloud layer out of the subcloud layer more quickly than new IN produced via crystal sublimation?

12. Figure 7b: Perhaps this is already explained, but why does the temperature warm more for recycling? Perhaps recycling induces activation which increase the release of latent heat? This should be discussed.

13. Figure 7d: Please explain the units m L^{-1} (meters/liter?).

14. Figure 10c (number in column): The feedback loop in figure 9 is not apparent in figure 10c as one would expect oscillations in N_{NI} to correspond with those in N_{IN}.

3 Technical Corrections

15. Page 11729, Line 10: "radiatively-important" should be "radiatively important".

16. Page 11729, Line 26: Please replace the semi-colon (;) with either a colon (:) or a comma (,).

17. Page 11729, Line 28: Please remove the first "or".

18. Page 11730, Line 11: Both "large-eddy" and "large eddy" have been used.

19. Page 11730, Line 13: While it may be obvious to most readers, please consider expanding D.O.E.

20. Page 11733, Line 7: "horizontal resolution" should be "horizontal resolutions"

21. Page 11733, Line 23: Please replace "amplitude" with "amplitudes".

22. Page 11733, Line 28: Please replace "...where the slope of liquid-ice static energy exceeds..." with "...where the slopes of liquid-ice static energy exceed..."

23. Page 11734, Line 28: Water vapor mixing ratio has already been defined.

24. Page 11739, Line 13: "Figure" should be "Figures".

25. Page 11741, Line 8: "control" to indicate the control case is sometimes capitalized and other times not.

26. Page 11742, Please consider absorbing the first paragraph into the second as the first paragraph contains only one sentence.

27. Figure 1: There is an overlap in the x-axes of the two plots. Also, the caption indicates “grey shading” that does not appear in the figure.

28. Figure 3: Please add a legend.

29. Figure 4: This caption is very difficult to follow. Perhaps consider removing the first three sentences as that information is contained in the image. Also, please add the “control” lines to Figs. 4B and D and legends to B-D.

30. Figure 6 and throughout: Please consider relabeling the number of ice crystals to something like N_i as N_{IN} and N_{NI} are very easily confused.

31. Figures 7a and b: Are IWP and temperature calculated for just within the cloud, within the mixed layer, or for the entire domain.

32. Figures 7, 8, and 10 are missing plot labels as referenced in the captions (e.g., a, b, c, d) and x-axes.

33. Figure 10: “CB”, “CL”, and “ML” should be defined in the caption. Also, what do the grey shaded columns indicate?