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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Large-scale subsidence promotes convection in sub-Arctic mixed-phase stratocumulus via enhanced below-cloud rain evaporation" *by* Gillian Young et al.

Anonymous Referee #1

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Review of "Large-scale subsidence promotes convection in sub-Arctic mixed-phase stratocumulus via enhanced below-cloud rain evaporation" by Gillian Young et al.

This study presents a very nice series of simulations to test the response of Arctic mixed-phase clouds to subsidence under several different scenarios. This is a very little studied topic for these clouds, and the topic is appropriate for ACP. The authors do a good job of presenting not just the results, but in providing in depth discussion for why the changes occur. However, I have questions about some of their process arguments, and the paper overall needs to be edited substantially for clarity and be made more concise. I recommend major revisions.

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Discussion paper

Major Comments:

1. This is an extremely long paper, by my estimate 10-11 thousand words. I appreciate that there are several sets of simulations to discuss, but I still found that the paper was very repetitive at times and the writing was not always clear or well organized. I think that it could be substantially shortened without removing any of the main points. I've pointed out several specific instances where improvements could be made below.

2. Page 13, Line 8. It seems that the authors have misread the plot. Altering Nice has a much larger impact than changing Wsub, not the other way around. This false interpretation is repeated in the conclusions on Page 27, Line 14. This is also an important point for understanding my next comment.

3. The primary hypothesis is that increased subsidence retards dry air entrainment, leading to higher LWP and increased rain formation. The former allows for greater cloud top radiative cooling while the latter allows for greater sub-cloud evaporation and turbulence production. My question though is why do you not see a similar response when decreasing Nice? When decreasing Nice, you have much higher LWP, more rain production and sub-cloud evaporation, but you do not seem to get much change to TKE. Some differences exist, but they are not nearly as large as the differences due to varying Wsub, even though the change in LWP is larger when varying Nice. Why do we not see a similar response?

4. It is odd to me that the authors consistently show dNrain/dt to talk about increased/decreased evaporation and not dqrain/dt (rate of change of rain mass). Just because there are more/fewer drops being evaporated doesn't necessarily mean that more/less rain mass is being evaporated. And it is the amount of mass that controls the latent cooling magnitude and feeds into turbulence. Showing rain mass and rain mass rates of change instead would help to strengthen their arguments. The same comment applies to snow sublimation.

Minor Comments:

5. The title doesn't seem to reflect the content of the paper well. The below-cloud evaporation is only given as one contributing factor to the promotion of convection in these clouds. Also, it is only one aspect of the subsidence issue among many that are discussed in the text.

6. The introduction has lots of good information, but I think that it is confusing sometimes about whether the results pertain to the subtropics, Arctic, or both. Also, I find the motivation for the study a little confusing in the last paragraph of the introduction. The focus is on CAO transitions, but most of the study is not focused on CAOs. Is decreasing subsidence associated with CAO transitions? If so, this has not been clearly stated, and the link to tests 1-3 is not clearly made later.

7. Page 3, Lines 13-16. So cloudiness and high pressure are correlated in subtropical marine environments, and anti-correlated in the Arctic? Why?

8. Page 5. The text describes tests 1, 2, and 4, but not test 3. The description of the control simulation should probably be given before describing the tests.

9. Page 7, Lines 27-28. Why do non-zero snow rates implicitly suggest heterogeneity in the snow field?

10. Figure 3. I can't tell which lines are dashed in Fig. 3f (although it's easy enough to figure out).

11. Page 9, 1st paragraph. Why higher LWP? The authors mention later that it is reduced entrainment of dry air, but that could be explicitly mentioned here.

12. Page 9, Lines 21-23. While I certainly agree that each individual droplet will be larger, I don't see why that necessarily means that the LWP must increase. In fact, I would probably expect the opposite response. For lower Ndrop, that you would get more rain production, fallout and evaporation leading to overall reduced LWP.

13. Page 10, 1st paragraph. The profiles of turbulent quantities seem almost unchanged with changing Ndrop, and the differences described are hard to see.

14. Page 11, Line 3. Why would the downdrafts facilitate precipitation production? I primarily associate downdrafts with liquid evaporation and reduction of precipitation.

15. Page 11, Line 14. How is Ndrop decreased? Ndrop is held constant in the simulations.

16. Page 11, Line 17. Smaller effect on Nrain than what?

17. Page 13, Lines 9-10. This sentence is confusing. Please rephrase.

18. Page 13, Line 12. More exaggerated than what? The CNTRL case?

19. Page 15, Lines 5-9. This seems like a minor detail that doesn't need to be discussed. Plus, the trends at 9hrs can't be used to understand how you arrived at the current state at 9hrs.

20. Page 18, Line 1. Increased snow sublimation compared to what?

21. Page 18, Line 13. Incorrect units on TKE.

22. Page 18, Lines 19-20. The discussion is repeating itself.

23. Page 19, Lines 3-5. This sentence is confusing. Please rephrase.

24. Page 21, Line 4. Cloud extent has never been shown. Or do you mean vertical extent? I had interpreted it as cloud fraction. I don't understand how the next sentence is a logical conclusion from this sentence.

25. Page 22, Lines 10-25. If the focus on this section is subsidence and microphysics, then these lines are not necessary.

26. Page 26, Section 4.5. I'm not sure what this section adds to the manuscript. All of the points seem to have been made already.

27. Page 27, Line 9. The authors have not shown that precipitation formation is enhanced in downdrafts.

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28. Page 27, Line 12. Wsub cannot possibly be in a feedback loop since it is held constant in the simulations.

29. Page 27, 3rd and 4th points. These points seem to mostly restate the first two conclusion points. In general, I think that the paper could be strengthened by highlighting just three or four main take-home points rather than nine.

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