Review of “Partitioning the primary ice formation modes in large eddy simulations of mixed–phase clouds” by Hande and Hoose

The authors have conducted LES for a few typical cloud cases to systematically investigate which ice nucleation modes dominate. The study has some interesting findings, such as, immersion freezing dominates and contact freezing also contributes significantly in all cases. At colder temperatures, deposition nucleation plays little role, and homogeneous freezing is important; the temporal evolution of the cloud determines the dominant freezing mechanism; precipitation is not correlated with any one ice nucleation mode, instead occurs simultaneously when several nucleation modes are active. However, I have some major concerns which could impact the key conclusions of the paper. Addressing these concerns would make a more solid paper.

Major comments:

(1) The results could be dependent on how dust aerosol particles are treated in the model (i.e., prognostic or fixed during the simulation). The information about this is lacking. If dust aerosol particle size distribution is fixed as constant, then cloud properties would not be realistic, especially results of the temporal changes would not be reliable. If prognostic, the relative importance of different modes could depend on the calling order of these modes in the code. For example, if contact freezing is called before deposition freezing and it is efficient, then a lot of interstitial aerosols would be consumed at low-levels (warm temperatures), which would decrease the transported aerosols reaching the cold temperature so the less contribution of deposition freezing will be seen. However, if deposition is called before the contact freezing, the results could be totally changed. The authors did say the dust aerosol concentrations are constant in the vertical dimension. Is it just at the initial time or during the simulation. If it is during the simulation, how is it be realistic? Different assumptions of vertical distributions of dust aerosol particles could also impact the relative contributions of different freezing modes. Perhaps some sensitivity tests on this would like to gain some ideas.

(2) The key conclusions would also be affected by different assumption of the ratio between the immersed and interstitial aerosols. The even ratio used in this study needs some justification (any literature showing such a ratio would do). If there is no justification for this, the generalization of the key results of this paper can be questioned.

(3) More analysis is needed, either to support a key conclusion point or to explain the results (see specific comments # 1, 9, 14, 15). Very often, the authors only describe the results but not go further to explain and understand why.

Specific comments:

1) P. 1, Line 10-12, how about changes of rain rate PDF? Also, I did not see significant results presented for the point “Precipitation is not correlated with any one ice nucleation mode”.

Since this is one of the key results, the corresponding correlation plots should be found easily in the result section.

2) P. 2, L14-15, which study? Also, suggest to use past tense consistently for describing what past work did. Currently, the author mixed the past tense with present tense for these descriptions.
3) P. 2, L22, I am confused here. How can deep convective clouds always have liquid water at cloud top? This might occur in mixed-phase clouds, but not the deep convective clouds.
4) P. 2, L32, need to clearly state which studies since no specific studies is mentioned yet in this paragraph.
5) Section 2, Model description: need more information about dust aerosol simulation in the model, for example, is the dust aerosol size distribution prognostic or fixed during the simulation? See my major comment #1 about the importance of the information. Also, about the vertical distribution, needs to clarify the constant concentration is just at the initial time or during the simulation.
6) P. 4, L15-17, I am not clear how the assumption of the ratio allows the relative concentrations of immersion and contact INPs to be compared independent of this assumption. In addition, is there any measurements in literature showing a ratio of immersed to interstitial aerosols in any place? This ratio could affect the relative contribution of different modes a lot. If there is no justification for this, the generalization of the key results of this paper can be questioned.
7) P.5, first paragraph, please describe that it is an orographic mixed-phase cloud case.
8) Figure 3, how to explain the two disconnected layers of liquid in this warm-bubble case? The layer between 9.5-13.5 km is not realistic. Temperatures in this layer could be lower than -38 ^{0}C, so liquid particles generally can not survive. So, why is there no liquid between 7.5-9.5 km?
9) p.7, L17, why are both lower and higher aerosol concentrations giving less precipitation?
10) P. 7, last paragraph, the sentence “While the stratiform case has moderate amounts of liquid water, the total precipitation is the lowest amongst all the cases, so much so that the precipitating liquid doesn’t decrease the total water” is confusing. The first part of the sentence does not mean much since all the cases are different type of clouds and comparing the correlation between liquid water and precipitation among different types of the clouds does not make much sense physically. Second, I am not sure what you really want to say here for the second part of the sentence “so much so that…”.
11) P.8, Section 4, this is a discussion session. Table 1 clearly shows main results, so I would suggest to present it earlier (i.e., in the result section).
12) P9, L9, do you mean the stratiform cloud investigated here has no in-situ cirrus?
13) P9, L22, what is “a fraction of a percent”?
14) P9, L25-26, what makes “contact freezing dominated at warm temperatures”? Why immersion freezing is less contributed?
15) Last paragraph: Need to explain why the perturbation in aerosol concentrations (means increase or decrease of aerosols) produced proportional changes in the relative contribution of immersion freezing INPs and the relative contribution of the other modes decreased the convective cases. It is especially important to understand how all the other

modes are decreased for both increasing and decreasing aerosols. Also, what makes the different results of aerosol impacts among the convective, orographic, and stratiform cases?

Minor comments,

P. 1, L6, “in each case” should be “between the cases”.

P9, L3, change “an orographic mixed–phase case” to “orographic mixed–phase clouds”.

16) P9, L6, incomplete sentence: “There is a fundamental difference between cirrus produced in different dynamical environments”, between cirrus and what?