

Review of Liu and Shi, 2021: Estimating the potential cooling effect of cirrus thinning achieved via the seeding approach

The reviewed manuscript presents climatic impacts of various seeding strategies in CAM5 general circulation model. In particular, the authors focus on a newly developed optimal seeding method that injects just the right amount of ice nucleating particles (or ice crystals, as suggested in the text) to prevent the formation of homogeneous freezing. Interestingly, seeding was found to modify liquid and mixed-phase clouds in ways that counteract part of the climatic cooling effect at cirrus levels. Such adverse effects can be limited by seeding only areas with solar zenith angles larger than 12° .

The manuscript is nicely structured, has a clear message, and presents the model results in a convincing way. The optimal seeding method is an innovative new way of implementing cirrus cloud seeding in ice nucleation schemes. I recommend publication after minor revision.

General comments:

I.) Why is homogeneous freezing switched off at temperatures colder than -68°C ? I don't think there is enough evidence from observations for such a drastic modelling choice. Does this decrease the uppermost tropospheric ice crystal number and in such way brings the model closer to the observations? Does this condition influence upper tropospheric RH_{ice} ?

Would cirrus clouds have a stronger warming effect if you allowed freezing also under the coldest temperatures? Would that increase the radiative impact of cirrus seeding?

II.) What is the spatial and temporal variability of seeded ice crystals in the OPT scenario within a certain region/time? E.g. does the optimal seeded ice crystal number remain constant on the 0.5/1/2/7/24/90-day timescale within a certain area? Would the OPT seeding strategy be feasible in real world or in parts of the world, or should we think of it as a purely academic experiment?

Also, please specify whether you seed at every model timestep in INP20 and INP200 strategies. Would the OPT scenario with a decreased seeding frequency still deliver a significant cooling effect?

Minor comments:

page 1, line 20:

conserving energy => probably meant "saving energy"?

page 1, line 23:

...as a back-up tool to against...

page 2, line 30:

The sentence

“...which allows more longwave radiation to escape into space so that cool the Earth...” should be rewritten.

Maybe: which allows more longwave radiation to escape to space, leading to a cooling effect on the planet.

page 2, line 39:

“...and even the strongest cooling effect may not be ideal”

What do you mean with this sentence, please explain!

page 2, lines 60-62:

The sentence on lines 60-62 sounds a bit weird and may need to be rewritten. A suggestion: Therefore, seeding the clouds with a few INPs can prevent the Sice to reach the threshold needed for....

page 3, line 63-64:

Not sure if we can draw a direct connection between decreased ice crystal number concentrations and the name “cirrus thinning”. I believe it would be more intuitive for the reader to add the intermediate step of decreasing the cirrus cloud optical depth (as a result of less N_i), which is probably where the name thinning is coming from.

page 3, line 93:

Could you add a reference for the sentence starting with “*Notably, in terms...*”

Fig.1: Why does the dashed line representing S_i for HET simulation stop at about 60%? Shouldn't it continue increasing even after that point?

page 5, lines 136-137:

I am confused by the two sentences here. The first one (“*In the INP20 and INP200...*”) suggests you implemented seeding by simply increasing the N_{dust} by 20/200 particles L^{-1} . The sentence “*Note that N_{dust} ...*” suggests exactly the opposite. So that you keep the N_{dust} unchanged and you modify the N_{seed} . Could you therefore explain more thoroughly how did you introduce the seeding particles?

page 8, lines 97-98:

Does this mean that in CAM model a substantial fraction of mixed-phase clouds is formed by sedimenting cirrus?

page 8, line 200-201:

Why - Are the regions where IWP increases connected to a more vigorous deep convective activity?

page 10, line 239:

“...is used to show how many proportions of iCRE are eliminated...”

please rewrite, for instance as: ...is used to show what proportion of iCRE is eliminated...

page 12, title 3.2:

It's probably better to use “with” instead of “regarding”.

page 12:

Another motivation for R10 experiment is probably the smaller mass of the 10 micron ice crystals, compared with the 50 micron one (?)

page 15, line 350:

regarding the => with the/using the

page 15, line 353:

the global cool effect => the global cooling effect

page 15, line 354-355:

The sentence starting with "*Because there are...*" should be rewritten. Maybe:
Avoiding seeding over low-latitude regions can limit some warming effects due to changes in mixed-phase and liquid clouds and thus lead to a more pronounced global cooling effect.

page 16, line 360:

maybe better: The overall cooling effect was maximized when using a solar zenith angle threshold of 12°.

page 16, line 363:

the sentence "*It is still possible...*" should be reworded. Maybe:
The global cooling effect can thus be maximized when limiting seeding to most suitable regions and times of the year.

page 16, line 364:

"...in the next step" => in our future work.

page 17, line 395: efficient => effective (?)