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A comprehensive estimate of the global cooling effect from hindering homogeneous ice nucleation under cirrus conditions with CAM5

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The warming effect of cirrus clouds is well-known. In recent years, in order to mitigate global warming, cirrus cloud thinning as a newly emerging method of geoengineering has been studied based on climate modeling. Adding a few (~10 L^{-1}) INPs (ice nucleating particles including ice crystals) might hinder homogeneous ice nucleation, which can produce a large number of ice crystals (~1000 L^{-1}), and then reduce cirrus clouds. On the other hand, the cirrus clouds might increase if too much INPs were added. Therefore, the effectiveness of cirrus seeding on cooling our earth is still in debate. In this study, we developed a method (optimal seeding scheme) to calculate the minimum concentration of seeding INPs, which is just enough to prevent homogeneous nucleation from happening. Simulation with the Community Atmosphere Model version 5(CAM5) using the optimal seeding scheme shows a significant cooling effect (–1.4 W/m^2), which is equal to two-thirds of the cooling potential (–2.1 W/m^2) derived from the pure heterogeneous simulation (i.e., homogeneous ice nucleation is artificially switched off). Seeding fixed 20 L^{-1} and 200 L^{-1} concentrations of INPs show the global average radiative effect at –0.5 W m^{-2} (cooling) and 0.1 W m^{-2} (warming), respectively. The cooling effect of seeding fixed number concentration of INPs is not obvious, which is consistent with previous studies. Furthermore, using the optimal seeding scheme, the sensitivities of cooling effects to seeding area, ice nucleation parameterizations and homogeneous ice nucleation occurrence frequency are also investigated.