Dear Johannes Quaas and both referees,

First, thank you to both referees for your (many) helpful comments. We will post our response to your comments as individual replies and address major changes here first. All our text is in blue.

It has taken relatively long to reply and write a revision due to the discovery of several bugs relating to the treatment of ice in our simulations. This required careful re-running of simulations and re-interpretation of some results.

In this Author Comment we first summarize four major changes since the initial submission:

1. Changes due to bug fixes in the radiative transfer calculations
2. Introduction of sensitivity experiments
3. Rewriting of the introduction sections
4. Revised interpretation of 'cloud gap' experiments

On behalf of both authors,

Wouter Mol

1. Bugs in radiative transfer calculations involving ice

There were 3 bugs in the radiation code that noticeably affected all simulation with ice particles (figures 13, 14, 15, and 16):

1. The effective radius for ice was cut off to the limits for liquid water due to a bug in the code, and therefore optical properties and phase function were biased towards smaller droplets
2. Mie phase functions for ice particles was not implemented, the code silently switched to the lowest value for water droplets. Scattering through ice was thus effectively too diffuse
3. Ice optical property in the upstream RTE+RRTMGP lookup tables were defined in diameter, but were marked as radius in the metadata. . This resulted in effectively using too small effective radii, making ice clouds more optically thick

Bugs 1 and 3 have been fixed and bug 2 avoided by using Henyey-Greenstein (HG) in favour of untested Mie tables for ice. Simulations containing ice were performed again, which means figures 13, 14, 15, and 16 are updated with new data.

The combined effect of all fixes is that ice clouds now have a visibly lower optical depth than before. This has brightened up the area under anvil clouds by 10% and further increased the sunlit side any updraft. See the figure below for an example.

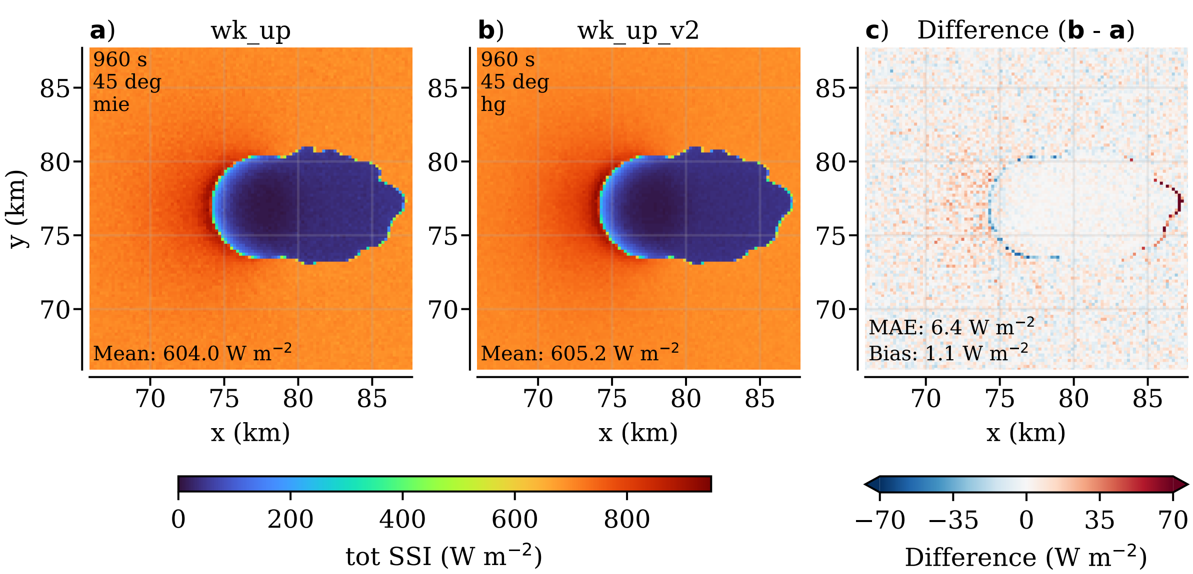

Figure 1: old (a) compared to new (b) before any ice formation in the deep convection simulation without wind shear. This only shows the effect of HG vs. Mie phase function as there are no ice clouds yet present.

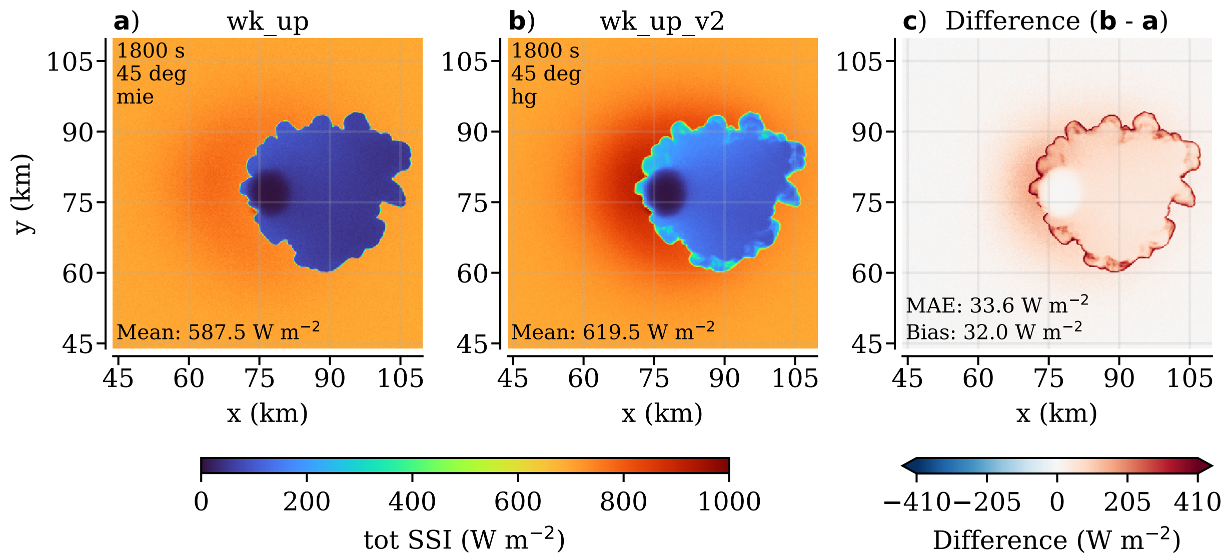

Figure 2: old (a) compared to new (b) simulation illustrating how the anvil cloud (all ice) has become more optically thin.

2. Introduction of sensitivity experiments

The simulation-related issues and questions by the referees (see below) prompted us to run a set of sensitivity experiments to test the robustness of the simulations in response to the choice of phase function (Mie vs. HG) and droplet number concentration (indirectly effective radii). New figures are added to the appendix of the revised manuscript and are discussed in the methods section 3 and results section 5.

The text describing droplet number concentrations has been changed to reflect actual values being used:

- Nc0 was hardcoded to 1e8 for water and did not use the value in the .ini as reported originally (2.5e8)
- Nc0 was different for water and ice, and therefore the effective radius was too. This is now clarified: Nc0 = 1e8 for water and 1e5 for ice by default.

3. Revised introduction and background sections

Our original introduction, Section 1.2, and Section 2 fell short in introducing and motivating our work in the right context, as pointed out by both referees. The introduction has been largely revised, the details of which we include in our response to the referees.

4. Different interpretation of ‘cloud gap’ experiment

We received comments from Dr Giorgi Yordanov, whose work we cite in relation to the cloud gap experiments. From this we learned that the way we design our cloud gap simulation limits the potential of forward escape to generate highly focused extreme enhancement (up to x1.8 clear-sky), due two factors: too high optical thickness (downward escape regime) and cloud gap radius well above the apparent size of a solar disk.

Clouds may be configured such that a gap has an apparent size similar to the solar disk (0.5 degrees), the optical thickness is optimal (tau = 3.1 is their theoretical optimum), and with unobstructed direct irradiance. This would theoretically create a ring of cloud edges that creates a focused area of enhanced irradiance due to forward scattering. The figure below indirectly illustrates this. Making the gap small enough to focus this ring into one point would also close the gap to direct irradiance, unless the simulation is run at meter-scale resolution and the Sun is just a few degrees away from the zenith. We deem such a configuration unrealistic, despite it being an interesting theoretical limit.

We now clarify the difference between our experiments and that of Georgi Yordanov. We believe that small gaps in stratus or between altocumuli result in SSI patterns with significant irradiance enhancement exactly as already stated in our initial submission. However, we add that under rare conditions we are underestimating SSI maxima due to resolution, which limits the potential for forward escape to add more SSI focussed on the sunlit area.

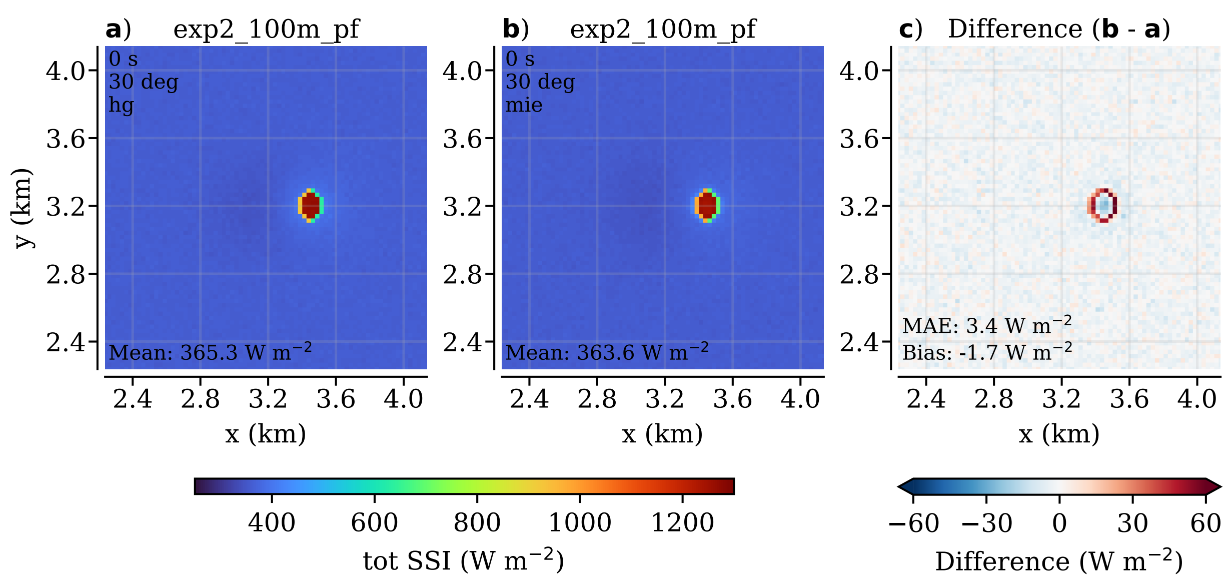

Figure 3: Phase function choice highlights a ring of enhanced SSI for Mie scattering relative to Henyey-Greenstein (this is new Figure A1)