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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Studying an effect of salt powder seeding used for precipitation enhancement from convective clouds" *by* A. S. Drofa et al.

Anonymous Referee #1

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General comments

This paper presents experimental and numerical studies of hygroscopic seeding of warm clouds using salt powder. Traditionally it has been believed that hygroscopic seeding by pyrotechnic flares broadens the droplet size distributions of cloud droplets in seeded clouds in comparison to non-seeded cases. This results in a higher number of larger cloud droplets which enhance the collection process and thus precipitation formation. Furthermore, the cloud droplet number concentration decreases as a result of preferred activation of the larger particles which reduces the supersaturation. Numerous experimental and operational cloud seeding programs have been conducted

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Discussion Paper

using this hypothesis but ignored any further testing of this assumption on the exact microphysical effect that pyrotechnic flares impose on the drop size distribution. Recently experimental and numerical studies have been published that caution operational programs on the operational use of hygroscopic seeding using pyrotechnic flares. This paper addresses some of these relevant fundamental questions pertaining to hygroscopic seeding and studies the exact effect of hygroscopic seeding using salt powder (but not pyrotechnic flares).

Specific comments

Pg. 10743

The 'Introduction' to the paper fails to identify the current hygroscopic seeding hypothesis. In principal flares should produce coarse mode particles to introduce giant CCN in clouds. Thus, smaller particles do not get activated and the total number concentration is reduced. This is referred to as the 'competition effect'. Another possible effect is the 'raindrop embryo effect' in which giant soluble particles can immediately become raindrop embryos. In some cases, one of the effects may be active, while in other cases, both effects may become effective, depending on the updraft velocity (i.e. supersaturation) and the amount and size of seeding particles. A discussion along these lines would be beneficial in the 'Introduction'.

Pg. 10748

Hygroscopic particles in the fine particle mode can become important in cases with high updraft velocities and when high water vapor supersaturation is reached. What is the maximum water vapor supersaturation reached in the chamber? What would be the minimum aerosol size activated at this maximum supersaturation? This needs to be described or discussed for these experiments to be put in context of atmospheric clouds.

Pg. 10751

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Rosenfeld et. al. (2010) discuss that the potential broadening of the drop size distribution at cloud base by the competition effect occurs when the seeding agent has still not diluted much, and hence affects a very small cloud volume that dilutes quickly. Therefore, the main expected effect of the giant CCN is probably serving as raindrop embryos. I would like the authors to address the issue of 'the competition effect' and 'raindrop embryo effect' more comprehensively using their cloud chamber data. How much dilution is needed for the competition effect to 'dilute'? Can this be quantified from the chamber data? Can the chamber data describe the activation of drops by the raindrop embryo effect? If yes, it needs to be described. If not, describe how your chamber results relate to observations of these effects by others (Mather et. al. 1997, Ghate et. al. 2007, Rosenfeld et. al. 2010).

Pg. 10755

The 1-dimensional cloud model does not simulate ice processes. For continental clouds to produce rain, ice processes need to be considered. The authors do not address this subject at all. How does ignoring ice process effect the model calculations and precipitation computations? How can statements such as those in Pg. 10760 Line 27 (precipitation amounts from clouds 2.5 <H<3.5km) be supported without any treatment of ice microphysics? Justification or more explanation is needed.

In addition, no mention is made of the work by Kuba and Murakami (2009). How does the study presented in this paper relate to the work by Kuba and Murakami?

Pg. 10763 Line 8-13: The conclusion states:

"In summary, the experimental data and the results of numerical simulations presented demonstrate the great promises arising from the use of the salt powder studied for obtaining additional precipitation amounts from convective clouds when accelerating the coagulation results in additional rainfall on the ground. Thus it is proposed to recommend using this salt powder in the seeding experiments in the natural atmospheric conditions.

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As written, this conclusion is unacceptable to the reviewer. The authors should not summarize that their study demonstrated 'great promises' nor that their study shows any result of 'additional rainfall on the ground'. The authors should not recommend the use of 'this' salt powder. A major rephrasing of this conclusion is needed. The conclusion should summarize the results accurately and support the interpretations of this work. Recommendations for future work should be identified and focus on the needed steps for a confirmation of the hygroscopic seeding hypothesis.

Technical corrections

Pg. 10742 Lines 23-24: "Here we show that seeding at rather low consumption rate of the salt powder precipitation can be obtained from otherwise non precipitating warm convective clouds."

Try instead: "Here we show that seeding at rather low consumption rate of the salt powder initiates precipitation from otherwise non precipitating warm convective clouds."

Pg. 10743 Lines 23-25: "The paper presents the results of experimental and theoretical studies of cloud modification with the salt powder developed at the Hebrew University, Israel, for obtaining additional precipitation amounts from convective clouds."

Try instead: "The paper presents the results of experimental and theoretical studies of cloud modification with the salt powder developed by Lahav and Rosenfeld (2005) and Rosenfeld et al. (2010) for obtaining additional precipitation amounts from convective clouds."

Pg. 10745 Line 12: I couldn't locate Romanov and Zhukoy (2000). This paper should be made available.

Pg. 10745 Line 19: "It usually makes 18–20 C."

Try instead: "It usually reaches 18–20 C."

Pg. 10745 Line 23: "As the total heat capacity of the BCC walls is by about 10 times

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greater than the total heat capacity of air in the chamber, the evolution of the cloud medium is more strongly aïňĂected by the processes of air heat exchange with the chamber walls."

Try instead: "As the total heat capacity of the BCC walls is 10 times greater than the total heat capacity of air in the chamber, the evolution of the cloud medium is strongly aïňĂected by the processes of air heat exchange with the chamber walls."

Pg. 10746 Line 1-2: Change "By 20 min after the cloud medium began to form the equivalent velocity of updraft drops to zero, the air temperature begins to rise and the cloud begins to evaporate."

Try instead: "After 20 min of cloud formation the updraft velocity drops to zero, the air temperature starts to increase and the cloud begins to evaporate."

Pg. 10746 Line 5: A reference is needed for the 'particle analyzer' if we are to understand the measurements.

Pg. 10746 Line 9-10: I cannot understand what is meant here. It seems like the author is trying to describe some optical principal or property which is not understandable.

Pg. 10746 Line 11: This paper is in Russian. Is an English version available? If not, the instrument should be described more comprehensively.

Pg. 10746 Line 24: Which airborne instrument is being referenced here? Provide an appropriate reference for this particular instrument.

Pg. 10747 Line 2: This paper is in Russian. Is an English version available? If not, provide more details about this measurement principle.

Pg. 10747 Line 19-20: "With the data of photoelectric analyzers calculated also are the integral parameters of size distribution functions such as concentrations and eïňĂective radii of the particles."

Try instead: "The integral parameters of the size distribution function such as concen-

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trations and eïňĂective radii of the particles are also calculated from the photoelectric analyzer data."

Pg. 10748 Line 1: "Then via the piping . . ." What piping? Please calrify.

Pg. 10748 Line 24-25: Clarify how the spectra are obtained.

Pg. 10749 Line 6: reference for microscopic studies is needed. Otherwise omit.

Pg. 10754 Line 14: extra coma after 'Drofa'.

Pg. 10756 Line 27 and 10757 Line 1: make reference to Fig. 1.

Pg. 10761 Line 1-2: Clarify this statement. It is not understandable as written.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 10741, 2010.