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Interactive Comment

Interactive comment on "Aerosols' influence on the interplay between condensation, evaporation and rain in warm cumulus cloud" *by* O. Altaratz et al.

O. Altaratz et al.

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Reply to reviewer #2: We would like to thank the reviewer for his beneficial remarks that helped us improving the manuscript. The scientific comments are highly appreciated and we tried to add as much as possible within the scope of the paper. The points that we couldn't discuss in details in this manuscript will be further discussed in our next papers.

Details regarding the dynamics and the precipitation efficiency were added to the manuscript according to the reviewer comments.

The new parts added to the manuscript are:

1) Section 3.2.1: "The appearance of the maximal value of the updraft in the cloud is delayed as the cloud is more polluted, in accord to the delay in rainfall initiation. The maximal values are 4.3 m s-1 for the clean cloud (at 34 min of simulation), 4.5 m s-1 for cloud 2 (at 44 min) and 4.4 m s-1 for the most polluted cloud (at 48 min)."

"The downdraft values at clouds top at 22 min of simulation are -0.6 m s-1 for the most polluted cloud and -0.2 m s-1 for the clean cloud, indicating higher evaporative cooling in the polluted cloud at this stage. Another evidence for that is the thermal gradient at cloud top height, between cloud core and margins, which is -0.4° in the clean case and -0.8° in the most polluted one."

2) Section 3.2.2: "The time evolution of the rain efficiency (rainfall divided by total amount of condensed water) is similar in trend to the rain rate (Fig. 6). It has the highest values for the clean cloud case during most of the simulation (with a peak value of 7%) it is lower for cloud 2 (with a peak value of 1.5%) and for the most polluted it is has the lowest values with a peak value of 1.3%."

Answers to the specific comments:

1) Page 12692, before line 20, model description: There are a few details the authors might want to provide: what are the lateral and vertical boundary conditions as well as initial wind field (I guess that is all zero, but needs to be told), whether radiation is included in the model (in case of no radiation, the authors might want to comment on the potential influence of this assumption on the results)? Also, what is the number concentration of particles larger than 300 nm in the clean case?

Since the interplay between condensation and evaporation as a function of aerosol loading is complicated and many feedbacks are involved, we tried to simplify all other variables. We did not included radiation (though this is extremely interesting topic and absorbing aerosols can induce additional feedbacks) and wind shear. These effects are being study separately. Details were added to the model description about the boundary conditions we used ("Open boundary conditions were assumed"). It is mentioned that no wind field is included in the initial conditions. Radiation is not included in the model. Since it is a small and short lifetime cloud and we assume the modeled aerosol are non-absorbing aerosol we decided to exclude the issues of radiation from this paper. We chose to limit the degrees of freedom in order to minimize the complexity of the problem. It is mentioned in the text now that "There are no radiation processes in the model".

The pollution aerosols were added to the background aerosol distribution only in one bin of 0.3 micron and not to all the bins bigger than this size.

2) Page 12693, paragraph 3, "The differences... ": the maximum droplet concentrations in all cases exceed the values described in the previous section for particles larger than 300 nm. A calculation could tell (since the Kohler equation was used) the likely value of the maximum supersaturation reached in various cases based on the prescribed aerosol spectra. This should be useful to understand the core strength and water budget among others. In addition, adding dynamic or thermodynamic results could enhance the discussion about evaporation here.

The maximum droplets concentrations mentioned in the text are the numbers of drops that were nucleated. The values described in the previous section (that are smaller) are the number concentration values of the pollution particles only (in the bin corresponding to the size of 0.3 micron) and they don't include the background aerosols concentration numbers. For clarity we added a description of dynamic and thermodynamic results: "The downdraft values at clouds top at 22 min of simulation are -0.6 m s-1 for the most polluted cloud and only -0.2 m s-1 for the clean cloud, indicating higher evaporative cooling in the polluted cloud at this stage. Another evidence for that is the thermal gradient at cloud top height, between cloud core and margins, which is -0.4° in the clean case and -0.8° in the most polluted one."

3) Page 12693, 3 lines from the bottom: 2200m vs. 2100m, it is only one grid interval. The difference in cloud top height at this step seems not significant.

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The line is changed:" At this stage, cloud top-height is almost similar for all clouds (2200 m for the clean cloud and 2100 m for the polluted ones)."

4) Page 12694, line 6, "indicating that there are... ": does this suggest that the cloud width has been changed due to aerosol effect? An averaged number would be helpful.

Information regarding the cloud width was added to the manuscript.

"There is a reduction in the value of the drop concentration and mass in the region between 1400-1800 m, indicating that there are regions in the polluted cloud margins that contain fewer drops (both in mass and number) than in the corresponding locations in the clean cloud. Moreover, there are differences in clouds width corresponding to the pollution loading. At this stage the mean width of the clean cloud is 404 m, for cloud 2 it is 357 m and for the most polluted cloud it is 347 m (the clouds boundaries are defined by the grid points with a mass mixing ratio greater than 0.01 g kg-1)."

End of section 3.2.1: "Yet the mean width of the clean cloud at this stage is still larger than those of the polluted ones (431 m for the clean cloud and 354 m for the most polluted cloud)."

Summary: "Due to these processes the width of the polluted clouds is smaller than for the clean clouds' width during most of the simulation time (14-56 min). Only at the end of the dissipation stage (that happens earlier in the clean case) it reverses and the clean cloud becomes smaller in the mean horizontal width."

5) Page 12694, generally on Figure 2 and 3: The maximum number concentration of droplet appears in the upper cloud at 20 minutes while near the cloud base in the later time particularly in the polluted cases, what are the corresponding dynamic features?

There are two centers of high drops number concentration, one is located near cloud base and the other one near cloud top. The one near cloud base is the core place for nucleation of new (small) droplets, and the center near the cloud top is due to accumulation of drops (driven by the updraft) near the top that are blocked by the evaporation downdrafts. There are changes in the dynamics during cloud lifetime that determine which center will be more significant during the different stages.

6) Page 12695, line 3: "a strong horizontal buoyancy gradient...", the modeled temperature change against aerosol number concentration should be able to tell whether this is the case.

Two paragraphs regarding this subject was added to the text (at section 3.2.1): "The downdraft values over clouds top at 22 min of simulation are -0.6 m s-1 for the most polluted cloud and only -0.2 m s-1 for the clean cloud, indicating higher evaporative cooling in the polluted cloud at this stage. Another evidence for that is the thermal gradient at cloud top height, between cloud core and margins, which is -0.4° in the clean case and -0.8° in the most polluted one."

"They hypothesized that the enhanced evaporation is responsible for a stronger horizontal buoyancy gradient which increases the vertical circulation around the core of the cloud, and increases dilution via entrainment (Zhao and Austin, 2005). The thermal gradient between clouds' core and boundary can represent the horizontal buoyancy gradient. It was checked for a horizontal plan at 1300 m height (the central part of the cloud) for the three clouds and the results show that during all stages of the clouds lifetime, the clean cloud has a smaller thermal gradient than the polluted clouds."

7) Page 12698, line 26: "the resultant downdrafts" was not specifically demonstrated in the previous text. The authors might want to add the discussion based on results, or describe it here as a hypothesis.

Information regarding the downdrafts at cloud top was added to the manuscript (section 3.2.1): "The downdraft values over clouds top at 22 min of simulation are -0.6 m s-1 for the most polluted cloud and only -0.2 m s-1 for the clean cloud, indicating higher evaporative cooling in the polluted cloud at this stage."

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 12687, 2007.