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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The breakup of levitating water drops observed with a high speed camera" *by* C. Emersic and P. J. Connolly

Anonymous Referee #1

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General comments:

This short paper reports on results from a small experimental study where large water drops were suspended in a wind tunnel, and collisions between them were recorded with a high speed camera. Currently raindrop breakup is parameterised based on experimental data from collisions between 10 drop size pairs collected by List and co-workers around 30 years ago. The data presented in this paper investigates a region of parameter space which has not previously been studied, and this fact makes the study worth publishing. There are some questions regarding how accurate a simulation of natural raindrops this experiment provides, but nevertheless this paper should provide a useful qualitative guide for future experiments and analysis.

The subject fits well into ACP's scope.

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While the bones of the manuscript are fairly sound, I have a number of comments, questions, and criticisms which I would like the authors to take on board. I therefore recommend the paper be accepted following major revisions.

Specific Comments:

1. Introduction. (a) I would like to see a more comprehensive review of previous experiments on drop collision-induced breakup, details of past attempts at parameterisation of the process, and the region of parameter space that was covered. Low and List and McFarquhar's papers provide much of this background info. Then you can explain how your new work fits into that background.

(b) I think what makes your data unique is (i) you sampled so many bag breakup events and (ii) your drop sizes were much bigger than any of the Low/List experiments, and so you can test whether it is really valid to extrapolate their data to those sizes. This should be brought out from the start.

(c) page 11740 line 25/26: Can you be more explicit about McFarquhar's point: I think he says that discrepancies between calculations based on Low and List vs observations means that a reexamination of the accuracy of Low and List's parameterisation is warranted, and he goes on to reformulate it.

2. Experimental setup: (a) page 11743 line 11-13. What effect on the results do you expect that the small drop impacting from the top rather than from below will have?

(b) 'we felt this approach was appropriate to address the aims of this study' - what are those aims? Should be spelled out in Section 1.

3.1 Results. (a) Say that drop-pairs broke up in 3 ways as found by other researchers: filament, sheet, bag. Now, according to McTaggart-Cowan and List (1975, JAS) there are actually FOUR breakup modes: filament, sheet, disc and bag. In his experiments he managed to sample only 3 bag events out of 712 breakups. So you may actually have the largest dataset on bag-type collision-induced breakup that currently exists.

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Perhaps bag breakup is favoured for these very large drops?

(b) For parameterisation purposes McTaggart-Cowan and List & Low and List lump their bag events in with the disc events. So I assume it is the parameterised disc fragment spectra you are comparing to? May as well say so.

(c) Drop approach velocity is stated to be 'comparable' to that for drops falling at terminal velocity. The figures in table 1 suggest that there can be a factor of 2 or more difference between the experimental and terminal approach velocities. This implies a factor of 4 difference in the collisional kinetic energy relative to natural raindrop collisions doesn't it? What effect might this have on your data?

(d) Fragment size spectra - can you explain the normalisation here - I assume you make it so that the sum of all 1mm wide bins = 1?

(e) Comparison with Low and List parameterisation. I am quite surprised at the curves for the Low and List spectra in Figure 3. They look nothing like the spectra for the drop pairs that Low and List actually measured, which all have quite well defined peaks. For example for sheet breakup I would expect to see a peak in the smallest bin and a peak where the large drop was (6mm bin). For filaments there would be these two plus a peak for the small drop (4mm). For discs/bags there should just be one big peak in the 1mm bin like in Figure 13 of Low and List part I (and indeed just like your measured drop spectra). But in all 3 panels the Low/List spectra are more or less flat, and seem to be almost identical for each breakup mode. This seems surprising - is it an artefact of extrapolating Low and List to these drop sizes, or is there a numerical error in your calculations?

(f) I tried reproducing these Low and List spectra from the equations in their paper, and had some difficulty. I used the equations in Low & List part II, with corrections from appendix of List et al (1987), as you stated you had done in Appendix A. So for example, for filament breakup, I tried to calculate the distribution of small fragments produced as the neck disintegrates. To do this one requires the parameter Ff1 from their (corrected)

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equation (3.3). Inputting DL=0.6cm and DS=0.4cm into eqn (3.3) gives me a large negative (ie unphysical) number for this parameter. I also had trouble calculating one or two parameters in the other spectra. Perhaps I have my calculations wrong, but it would be valuable to provide some details of what you obtained the distribution parameters to be for the various breakup types, and to give some detail of why the calculated spectra are so different from those plotted in part I of Low and List.

(g) I know Brown (1986, J. Clim. & Appl. Met.) has also found numerical difficulties with the Low and List formulation for certain drop pairs, and suggested some fixes. Likewise Brown (1995, JAS) and McFarquhar (2004) have also reformulated Low and List's parameterisation - it might be interesting to see if their calculations fit your data better.

(h) I think it would be useful to plot the continuous distribution function for the Low and List scheme on figs 3 as well as the totals in the coarse 1mm bins. You could still normalise the functions so that they are on the same scale (ie make the integral under the curve = 6, as the figure is currently plotted, I think?)

3.2 Simulations.

(a) line 11747 lines 24-26. Say Low and List suggest a maximum of 0.2-0.4% of breakup events are contributed by 4 and 6mm drop interactions. You need to specify an interval on the drop sizes for this statement to be meaningful, eg "0.2% of breakups are contributed by collisions between drops of 4-dD to 4+dD mm and drops of 6-dD and 6+dD mm in size, where dD is X mm".

4. Discussion

Some of this section is new and useful discussion; some of it is repetition of results from section 3, which are then reiterated again in the conclusions. I strongly recommend the discussion from section 4 is incorporated directly into sections 3.1 and 3.2 - this will make the paper flow better, and provides relevant discussion where it is needed. Then

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you section 5 sums up the main conclusions.

Other suggestions which might improve the paper:

page 11741 line 1-18 I think that this text is mostly tangential to the paper, and could be trimmed: really all you need to say here is that (a) collision-induced breakup is believed to be the dominant breakup process in natural rainfall; and (b) large drops such as the ones which you are simulating do exist in nature.

I know the editor has already suggested uploading your videos as supplementary material - I would also encourage this.

Consider moving Appendix A into section 3.1

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 11739, 2011.