Atmos. Chem. Phys. Discuss., 14, C1835–C1840, 2014
www.atmos-chem-phys-discuss.net/14/C1835/2014/

Atmospheric Chemistry and Physics
Discussions

Interactive comment on “Basic convective element: bubble or plume? A historical review” *by* J.-I. Yano

J.-I. Yano

jiy.gfder@gmail.com

Received and published: 25 April 2014

Reply to the Referee 2:

The following is the point–by–point response to the present referee’s comments. Many of the remarks below will also be incorporated into the revised text at appropriate places.

Grossing over many important points: This remark clearly resonates with the referee 1’s main point. Thus, please also refer to my response to the referee 1 as well.

In revision, the text will be substantially expanded as already described in response to the referee 1 and also described below so that key advantages and disadvantes of plumes vs. bubbles are also better undrstood.

Rennaisance of Bubble?: I believe more papers are coming out soon on bubbles. In revision I will quote oral presentations by George Craig (2012) and Alison Stirling (2013) as personal communications in order to strengthen this point. Furthermore, I strongly believe the laboratory experiments currently performed by Szymon Malinovski’s group can potentially elucidate the fine details of the bubble dynamics. In order to ellucidate this point, an image from their experiments (Fig. 1) will also be quoted in the revised manuscript. Note that these experiments can measure, with a help of particle image velocimetry (PIV: Korczyk et al. 2006), much more fine details of the flows associated with a bubble than current LESs can.

The following technical terms are more carefully introduced in the revised manuscript (in order of appearance): two–dimensional and three–dimensional flows (a reference textbook added), bubble, vortex ring, plume, entrainment, entraining plume, similarity theory, starting plume, detrainment, mixing line, jet.

Please refer to my response to the referee 1 in order to see some of the examples.

Five figures will be added in the revised manuscript: the four as given in reply to the referee 1, and a one as given as Fig. 1 in the present response.

It is important to note that the plume and the bubble are governed by different sets of equations in its simplest cases: compare Eq. (2) of Morton et al. (1956) and Eqs. (1), (3), and (4) of Turner (1963b). Note that their systems are described in terms of a vertical coordinate and time, respectively. However, even when the latter system is transformed into a vertical coordinate, it does not reduce to the former, because simply different physics are considered. When a stream of bubbles is considered, one must use the latter. In other words, although both may be arguably based on a certain “parcel" approximation, they are *not* equivalent.

Another way of looking at the issue is a mass–flux equation (Eq. 3 of the manuscript) that defines a vertical structure of the mass flux under a given fractional entrainment rate, which my be generally defined by $E/M = \alpha/R$ with R a radius of a cross section. Here, however, we obtain from the laboratory experiments, qualitatively different values for the fractional entrainment rate for entraining plume and a spherical bubble: $\alpha \simeq 0.2$ and 0.25, respectively (Turner 1969, 1986).

Note that the above argument is made under a hypothesis of non–interactions between the bubbles, as going to be emphasized in the revised Sect. 2. Little study has been performed on the interactions between the bubbles. Whether interacting ensemble bubbles behave as if like an entraining plume is just a highly speculative matter.

As also going to be emphasized in the revised Sect. 2, evolution of a bubble is highly transient in contrast to a quasi–steady nature of plumes. Thus, the most straightforward modification would be to take an ensemble of bubbles described by Turner's (1963b) Eqs. (1), (3), and (4) in place of an ensemble of steady plumes under a spectrum formulation of mass flux.

Under this new formulation, individual bubbles would behave in transient manner by explicitly taking into account of the convective time–scale evolution. [A subtle point that such a generalization is possible under a spectrum representation of mass–flux formulation will be carefully discussed in the revised Sect. 7: in the original manuscript, I skipped this subtlity in order to make the argument simple.] Under this formulation, a key constraint is to add a hypothesis of "collective steadiness" of those transient bubbles, which states that a total thermodynamic tendency of bubbles must be steady in convective scale in order to ensure the slow evolution of the large–scale dynamics.

As the referee suggests it may well be possible that ensemble of bubbles can be described under an analogy with a steady plume. However, in this case, the merit of adopting "bubble hypothesis" becomes more sutble and even implicit. Under such a re–interpretation, the entrainment–detrainment simply reduces to a tuning parameter.

The question is whether any fundamental bubble theory or extensive measurements of bubbles from laboratory experiments can provide anything useful for this "tuning" exercise.

In other words, if we are going to take a steady–plume system, as described in Sect. 7, merely as a mathematical entity, there will be no point for discussing any more which point of view is more central between bubble and plume. The entrainment–detrainment rate would simply becomes a tunable parameter, or something to be estimated from, say, LES without asking any physical mechanism behind.

It is a very good question whether we really need to worry about nonsteady convection in a parameterization. Many tend to lightly argue for it without reflecting what kind of modifications are required.

Some Minor Comments:

Everywhere: A native speaker will be sought in preparing the final manuscript so that many grammatical errors will be corrected.

3341:19: Importance of the dynamic pressure in the convective–plume dynamics is demonstrated by for example Holton (1973), Soong (1974), Yau (1979), and Kuo and Raymond (1980). Especially, Fig. 19 of Soon (1974) showed that the dynamic pressure force tends to substantially compensate out the buoyancy force. These new references are added in revision.

3342:24–28: A clearer description of starting plume will be introduced in revision.

References:

Holton, J. R., 1973: A one–dimensional cumulus model including pressure perturbations. Mon. Wea. Rev., 101, 201–205.

Korczyk, P., S. P. Malinowski, T. A. Kowalewski, Mixing of cloud and clear air in centimeter scales observed in laboratory by means of Particle Image Velocimetry. Atmos.

Res., 82, 173–182, 2006. DOI:10.1016/j.atmosres.2005.09.009

Kuo, H. L., and W. H. Raymond, 1980: A quasi–one–dimensional cumulus model cloud model and parameterization of cumulus heating and mixing effects. Mon. Wea. Rev., 108, 991–1009.

Soong, S.–T., 1974: Numerical simulation of warm rain development in an axisymmetric cloud model. J. Atmos. Sci., 31, 1262–1285.

Yau, M. K., 1979: Perturbation pressure and cumulus convection. J. Atmos. Sci., 36, 690–694.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 3337, 2014.

Fig. 1. A cross section of a thermal plume generated in a laboratory with use of a humidifier as a buoyancy source. Distribution of condensed water is shown by gray tone (courtesy : Anna Gorska).