

Interactive comment on “On the importance of cumulus penetration on the microphysical and optical properties of stratocumulus clouds” by S. Ghosh et al.

S. Ghosh et al.

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Referee 1

General and major comments

The main issue pertains to the effects of entrainment and mixing on the horizontal variability of the microphysical and optical properties of the four sectional runs. This is a pertinent issue and has now been included (see below). The other general comment is with regard to Figure captions. In the revised version we have presented more

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elaborate figure captions with all relevant details.

Major comments

1) Initialisation of the vertical velocity.

We fully recognise the fact that the choice of the magnitude of the initial vertical velocity is a crucial issue. As pointed out by referee 1, indeed like the ASTEX cases, the ACE-2 cases considered in the present study also showed a wide spectrum of positive and negative values for the vertical air velocity. The referee recommends that an objective approach would be to compute average updraught velocities, and use this number as a representative velocity. This is precisely what we have done - in the revised version of the paper we have stated this more clearly (see the top of the second column page 3 of the revised paper).

2-3) Importance of lateral mixing, entrainment and horizontal variability.

(Comments 2 and 3 are related and we therefore address them together).

Apart from Referee 1's general comments, the above issue is also raised in this referee's major comments 2 and 3. We now describe how we addressed these queries in the revised manuscript.

Referee 1 has pointed out the need to consider entrainment and mixing effects in the four sectional runs for the A560 case study. While we agree with the referee that horizontal variability in microphysical properties can occur due to turbulent mixing, and in particular due to entrainment at the cloud top, it is also important to note that for the case study in question the observed LWCs were nearly adiabatic. This suggests that although at the cloud top entrainment could have had some drying effects, for the main

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body of the cloud these effects were secondary. Nonetheless, it is an important issue and warrants a quantitative estimate, which we have now included. The importance of entrainment effects for the four sectional runs has also been pointed out by referee 2. In the revised version of the paper therefore we have examined the horizontal variability of the case study in question (A560 Polluted-2 case) in greater detail. In addition, as pointed out by the referee we have now included the additional reference of Los and Duynkerke(2000) in the revised paper (see p 6 column 1 para 3). We have used another parcel model developed by Mason and Jonas (1974) in order to account for entrainment and mixing and re-examined the issue of horizontal variability. This led us to modify the discussion on page p6 (see the bottom paragraph column 1 of page 6) where we have described the entraining parcel model by Mason and Jonas (1974). We modified Table 5 accordingly and included new text on p 6 column 2 of the revised paper where we have discussed the microphysical and optical properties with entrainment effects. From Table 5 we observe a modest amount of variability in the sectional runs. In particular, the optical depth τ in Run 4 is about 20% lower than in Runs 1,2 and 3. Although the relative humidity, the pressure, and temperature at the cloud base were not significantly different in the four runs (these were $\sim 99\%$, 12.5°C and 915 mb respectively), there were some differences in the average updraught velocities. The updraught velocities were 0.66, 0.71, 0.61 and 0.58ms^{-1} respectively. Since the mass dilution rate due to entrainment is directly proportional to the updraught speed, entrainment induced a modest, yet nonetheless, noticeable variability in the optical properties shown in the revised Table 5. (Please note that in the earlier version of the paper in Tables 4 and 5, the optical depth τ should have actually read $\tau/2$ i.e $\tau/2$ values were inadvertently stated as τ values. In the revised version, we have used τ values throughout).

4) Observed and modelled cloud thickness.

With regard to comment 4 of referee 1, we wish to point out that a confusion arose

because of the way we phrased our sentence. The sentence should have ideally described the two attributes separately - one describing the number concentration and the other the geometric thickness. We had written ..“This flight encountered unbroken cloudy regions (no drizzle was observed during this flight), and showed significant variability of the droplet number concentrations as well as varying cloud geometric thickness along the horizontal”. What we meant was that there were large variations in the droplet number concentrations and also showed *some* variability in the geometric thickness. In the revised version of the paper (see top of column 1 p 3 of the revised paper) we have suitably rephrased the sentence in order to rectify this ambiguity and have stated that the overall cloud depth was $\sim 300m$ and the overall variability in the cloud thickness were within 10%. In addition, in order to be fully consistent, we have also rephrased the paragraph preceding section 6 (see bottom of column 2 of p 6 and top of column 1 p 7 of the revised paper). We have now made it clear that with the inclusion of entrainment and mixing effects, some horizontal variability could be observed. However, the variabilities were not overwhelmingly large - for most parts of the cloud the LWC profile was still close to the adiabatic values.

Minor comments

1) Differences in the geometric thickness of the stratocumulus cloud.

The referee has wanted to know how the differences in the cloud geometric thickness were measured. In section 2.1 we have mentioned that the cloud LWC was measured with a Johnson-Williams hot wire probe. In addition the droplet number concentrations were measured by PCASP-100X and FSSP instruments. Profiles of LWC and cloud droplet number concentrations were used to infer the cloud geometric thickness.

2) Finally, we have also taken note of the last minor comment of this referee. The

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confusion arose because, in the first paragraph of section 7 (line 15 from the top of that paragraph) of the previous version of the paper we had inadvertently used the words 'optical depth' in place of the words 'effective radii'. We have now corrected this, and have stated .. " In particular, the minimum values of the effective radii were greatly influenced by the cumulus incursions and clearly corresponded to situations where the aircraft sampled cloud regions well within the cumulus tops that penetrated the stratocumulus base. See section 7 p 8 of the revised paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 4611, 2004.

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