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Atmospheric Chemistry and Physics Discussions

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

Anonymous Referee #1

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Review of the paper "On the importance of cumulus penetration on the microphysical and optical properties of stratocumulus clouds", by Ghosh et al.

General comments

The paper discusses droplet spectra computed by a parcel model. The strength of the paper is that observations collected during ACE-2 are used for the initialization of the model and for the validation of the modeling results. Although the model dynamics are rather simple, the microphysics results compare fairly well to the observations. However, the application of the model is limited. For example, as there is no lateral mixing involved, the parcel's liquid water content must approximately follow the wet-adiabatic lapse rate. Therefore, the four sensititivy tests performed to possibly explain the ob-

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served horizontal variability in microphysical properties appears to me as not making much sense, as the authors indeed find hardly any changes in the liquid water content if the input parameters are varied. It is more likely that the horizontal variation is due to turbulence, and in particular by entrainment at the top of the cloud layer. Last, I would like to recommend a modification of the figure and table captions, as most of the relevant information is given in the body text. A good caption should immediately explain the contents of the table/figure. For example, it can say whether the numbers are from observations or taken from the model, and it can explain the meaning of numbers in brackets. Now such relevant information is not given in the captions. Nevertheless, the quality of the paper is sufficient for publication after major revision. Please find some suggestions for revisions below.

Major comments

1) Initialization of the vertical velocity.

The choice of the magnitude of the initial vertical velocity is not trivial. Cumulus clouds that penetrate stratocumulus above were also observed from the MFR C130 during ASTEX, an exhibit a wide spectrum of both positive and negative vertical velocities, and I would not be surprised if similar results are found for flights A560/562. The same holds for stratocumulus. In this context, it is difficult to talk about initializing the model with "cumulus dynamics" or "stratocumulus dynamics". A possible objective approach is to compute average updraft velocities, and use this number as a representative velocity scale. Otherwise, the choice of the vertical velocity U used in the paper should be motivated in some more detail.

2) Lateral mixing, adiabatic profiles and optical depth.

Many parcel models take into account the effect of lateral mixing. For example, lateral entrainment of dry, unsaturated air into the cumulus cloud may be of particular importance for the evolution of the droplet spectrum. In addition, it will have a significant effect on the liquid water content, as lateral mixing tends to diminish the cumulus cloud

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liquid water content. Therefore lateral mixing affects the cloud liquid water path by its effect on the liquid water content, as well as by a possible change in the cloud droplet effective radius. The authors remark the importance of lateral entrainment, so why not taking into account this process?

3) Adiabatic profiles and horizontal inhomogeneity.

Cloud inhomogeneity is most likely to be explained by entrainment at the top of a stratocumulus cloud layer. For example, updrafts in stratocumulus transport relatively warm and moist air, whereas downdrafts incorporate some air from just above the inversion which is relatively dry, and may have a different chemical composition. Results from Large-Eddy Simulation models on a large horizontal domain show the development of mesoscale fluctuations in the cloud liquid water path, which can be explained by turbulent motions only. Because cloud-top entrainment and lateral entrainment are not implemented in the model, the model is not capable to explain the horizontal inhomogeneity. Recently, horizontal inhomogeneity in ASTEX stratocumulus clouds, which are similar to the ACE-2 flights studied, has been extensively discussed in a paper by Los and Duynkerke (2000) published in the QJRMS, pages 3287-3307.

4) Inconsistencies in the observed and modeled cloud thickness.

There appears to be some inconsistency in the paper. First it is stated that there were significant differences observed of the geometric cloud thickness. Then the four sensitivity tests give a difference for the cloud thickness of maximum 4 m (which is due to the lack of lateral mixing which forces any parcel to have wet-adiabatic thermodynamic properties). Last, it is stated in the conclusion that "the optical properties ... can be assumed to be reasonable estimates for the whole cloud", which seems to be in a contradiction with the previous statements. If the model would be capable to reproduce the observed differences in cloud depth, this would naturally lead to much larger differences in the optical depths.

Minor comments

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p6. How were differences in the geometrical thickness of the stratocumulus clouds measured?

p6. The sentence "the minimum values of the optical depth were greatly influenced by the cumulus incursions and clearly corresponded to the situations when the aircraft sampled cloudy regions well within the cumulus cloud tops that penetrated the stratocumulus base" is not very clear. One would expect a local increase in the optical depth at places where the cumuli penetrate stratocumulus, but at positions where this not occurs one may expect the same minimum values for the optical depth? It is not exactly clear to me what the authors are aiming at.

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