Entrainment Rates at the Tops of Laboratory Analogs of Cumulus and Stratocumulus Clouds

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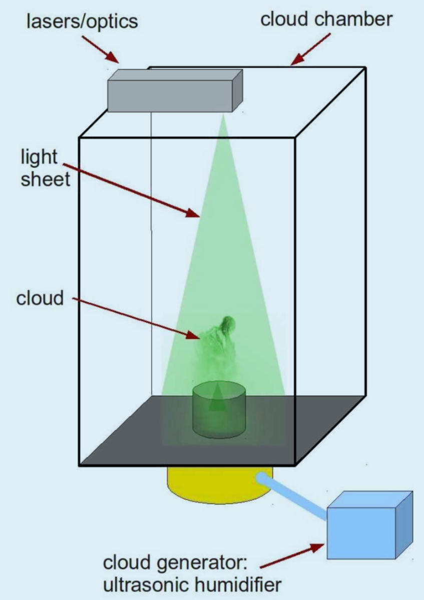
A Introduction

Understanding entrainment of non–turbulent environmental air into turbulent convective clouds is still challenging (e.g. de Rooy et al., 2013; Wood, 2012). The aim of our experiment is to create laboratory analogs of cumulus and stratocumulus clouds tops in a cloud chamber in order to study details of entraining structures by means of Particle Image Velocimetry (PIV).

B Experimental setup

We modify an experimental setup used previously by Korczyk et al. (2012). Cloud analogs created in the laboratory chamber consist of real saturated air and real water droplets. Vertical profiles of temperature and humidity in the chamber are monitored by vertical arrays of thermometers and hygrometers. We record series of ~700 images (1280×1024 px, 13×10 cm) of cloud cross–sections spaced 10 ms apart.



C Entrainment / detrainment rates

We process obtained images with an upgraded mutiscale PIV algorithm (Korczyk et al., 2012) to retrieve 2D velocity fields in a vertical plane cut through the cloud layer. With image processing we are able to indicate cloud-clear air interface. Extracting velocity fluctuations which are related to cloudy (u_i) and non-cloudy (u_a) air on both sides of the interface allow us to calculate entrainment / detrainment rates using the definition: $\delta = \rho_a(u_a - u_i)$, $\delta < 0$ - entrainment rate and $\delta > 0$ - detrainment rate. To calculate air density (ρ_a) we use temperature and relative humidity measured in the chamber.

D Initial conditions

E Overshooting cumulus

F Stratocumulus top

J Conclusions

- simulated Cu cloud: double vortex structures like in Damiani and Vali (2007)
- simulated Sc cloud: similarities to LES simulations e.g. (Kurowski et al., 2009) and in-situ data e.g. (Malinowski et al., 2013)
- typically, entraining eddies in Cu and Sc rotate in opposite directions
- simulated static stability and temperature inversion
- higher entrainment / detrainment rates for an analog of cumulus than in analogues of stratocumulus

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M References

R. Damiani and G. Vali. Evidence for tilted toroidal circulations in cumulus. J. Atmos. Sci., 64(6):2045–2060, 2007.

W. C. de Rooy, P. Bechtold, K. Frohlich, C. Hohenegger, H. Jonker, D. Mironov, A. P. Siebesma, J. Teixeira, and J.-I. Yano. Entrainment and detrainment in cumulus convection: an overview. Q. J. R. Meteorol. Soc., 139:1–19, 2013.

P. M. Korczyk, T. A. Kowalewski, and S. P. Malinowski. Turbulent mixing of clouds with the environment: Small scale two phase evaporating flow investigated in a laboratory by particle image velocimetry. PhysicaD, 241:288–296, 2012.

M. J. Kurowski, S. P. Malinowski, and W. W. Grabowski. A numerical investigation of entrainment and transport within a strotocumulus–topped boundary layer. Q. J. R. Meteorol. Soc., 135(638):77–92, 2009.

S. P. Malinowski, H. Gerber, I. Jen-LaPlante, M. K. Kopeć, W. Kumala, K. Nurowska, P. Y. Chuang, and K. E. Haman. Physics of stratocumulus top (POST): turbulent mixing across capping inversion. Submitted to Atmos. Chem. Phys., 2013.

R. Wood. Stratocumulus Clouds. Mon. Wea. Rev., 140(8):2373–2423, 2012.

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