Turbulent mixing in the bulk of a cumulus cloud

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Atmospheric clouds play a significant role in weather regulation and climate formation. In particular, number density and size distribution of liquid-water content define optical properties of clouds and modulate the radiation budget at the surface of the Earth. The impact of turbulent mixing of dry air with moist air on the droplet size distribution is studied deep inside a warm ice-free cloud. A simplified cloud mixing model was implemented therefore which summarizes the balance equations of water vapor mixing ratio and temperature to an effective advection-diffusion equation for the supersaturation field $s(\mathbf{x}, t)$. Our three-dimensional direct numerical simulations connect the scalar supersaturation field and fluid flow to the cloud droplet dynamics, in particular to the droplet size distribution for different box sizes, such that the Reynolds numbers of the turbulent flow increase correspondingly[1].

In addition, finite-time Lyapunov exponents are monitored such that we can relate regions of high compressive strain to those of high local supersaturation amplitudes. We find that the mixing process in terms of the droplet evaporation is always homogeneous in the bulk of the cloud, while being inhomogeneous in view to the relaxation of the supersaturation field. The distributions of the compressive finite-time Lyapunov exponent λ_3, the supersaturation field, and the droplet size are found to be basically Gaussian. The probability density function of λ_3 is related to the one of s by a simple one-dimensional aggregation model of scalar filaments which was originally develeoped for passive scalar mixing at high Schmidt numbers.

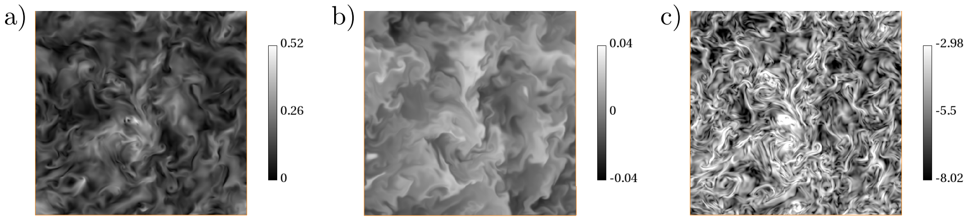

Figure 1: Contour plots in two-dimensional slices through a three-dimensional cubical volume. We show (a) velocity magnitude, (b) supersaturation field and (c) logarithm of the dissipation rate of turbulent kinetic energy for cubic domain with length size $L = 0.512$ m.

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[1]Pushenko and Schumacher, *arXiv*:**2303**.04632 (2023)