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Turbulent dispersion in cloud-topped boundary layers

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Abstract. Compared to dry boundary layers, dispersion in cloud-topped boundary layers has received less attention. In this LES based numerical study we investigate the dispersion of a passive tracer in the form of Lagrangian particles for four kinds of atmospheric boundary layers: 1) a dry convective boundary layer (for reference), 2) a "smoke" cloud boundary layer in which the turbulence is driven by radiative cooling, 3) a stratocumulus topped boundary layer and 4) a shallow cumulus topped boundary layer.

We show that the dispersion characteristics of the smoke cloud boundary layer as well as the stratocumulus situation can be well understood by borrowing concepts from previous studies of dispersion in the dry convective boundary layer. A general result is that the presence of clouds enhances mixing and dispersion – a notion that is not always reflected well in traditional parameterization models, in which clouds usually suppress dispersion by diminishing solar irradiance.

The dispersion characteristics of a cumulus cloud layer turn out to be markedly different from the other three cases and the results can not be explained by only considering the well-known top-hat velocity distribution. To understand the surprising characteristics in the shallow cumulus layer, this case has been examined in more detail by 1) determining the velocity distribution conditioned on the distance to the nearest cloud and 2) accounting for the wavelike behaviour associated with the stratified dry environment.

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