Geophysical Research Abstracts
Vol. 19, EGU2017-12809, 2017
EGU General Assembly 2017

Wind Shear Effects within the Entrainment Zone of Stratocumulus

Bernhard Schulz and Juan-Pedro Mellado
Max Planck Institute for Meteorology, Hamburg, Germany (bernhard.schulz@mpimet.mpg.de)

Stratocumulus clouds are crucial for the Earth's radiative budget and are hence thought to be important for understanding climate change. Still, atmospheric models suffer from order-one uncertainties associated with these clouds. Cloud-top entrainment is particularly challenging because of the small-scales associated with it. Convective instabilities driven by evaporative and radiative cooling of the stratocumulus cloud-top set a continuous encroachment of the cloud layer into the entrainment interfacial layer (EIL), a process defining the entrainment velocity. Wind shear might play an important role in enhancing the entrainment velocity, but has been largely overlooked in the past decades. Therefore, direct numerical simulations focusing on meter and sub-meter scales are used to investigate the interaction between a mean vertical shear and the entrainment velocity.
Our main findings are as follows. First, wind shear effects stay localized within the EIL, whose thickness is proportional to the shear layer thickness. This implies that the in-cloud turbulent state is independent of the imposed wind shear as long as the EIL is much thinner than the cloud layer. Therefore, a strong mean wind shear does not necessarily weaken the in-cloud turbulent state by depleting the cloud, which contradicts conjectures based on previous large eddy simulations. Second, a critical nondimensional shear number S_{crit} exits, such that no significant additional cloud-top cooling is created for $S < S_{crit}$, showing that wind shear effects are negligible in this regime. In contrast, a strong wind shear with $S > S_{crit}$ enhances cloud-top cooling significantly by amplifying radiative and evaporative cooling. For typical atmospheric conditions with a strong capping inversion, S_{crit} corresponds to a shear velocity of $1 - 2\,\mathrm{m\,s^{-1}}$. Consequently, large scale convective motions inside the cloud layer, associated with velocities of $\sim 1\,\mathrm{m\,s^{-1}}$, are unable to significantly enhance cloud-top forcing of the in-cloud turbulence. Third, we show that choosing different inversion points introduces order one deviations in the shear enhancement of the single contributions of the entrainment velocity, as for example radiative and evaporative cooling. Likewise, deformations of the cloud top introduce order one deviations among the different entrainment velocity definitions. Even for a quasi-steady state, where the entrainment velocity is equal for all inversion points, the partitioning between the single contributions depends strongly on the choice of the inversion point.
In sum we find that a strong mean wind shear enhances cloud-top cooling significantly and that the choice of the inversion point is nontrivial. Hence parametrizations of the different contributions of the entrainment velocity should be done in a consistent way (assume the same inversion point) and should consider shear effects. However, large scale convective motions within the cloud layer do not enhance cloud-top cooling, implying that their effects need not be retained in parametrizations.