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Turbulence properties in coupled and decoupled stratocumulus-topped boundary layers

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In marine atmospheric boundary layer (MBL), turbulence plays an important role in vertical transport of mass, heat and moisture, which is crucial for the emergence and evolution of stratocumulus clouds. We use high resolution in situ measurements of flow velocity, temperature, humidity and liquid water content performed from the helicopter-borne platform ACTOS in the region of Eastern North Atlantic in the course of ACORES campaign to compare turbulence properties in coupled and decoupled stratocumulus-topped boundary layer. Derived parameters include turbulence kinetic energy, its production and dissipation rates, anisotropy of the inertial range, turbulent fluxes of sensible and latent heat as well as characteristic lengthscales.

Inside the observed coupled MBL, turbulence is intensively produced by buoyancy at the cloud top and at the surface, and dissipated with equal rate across the entire layer depth. Turbulence is close to isotropic and inertial range exhibits scaling relatively close to that predicted by Kolmogorov theory. Inside the decoupled MBL properties of turbulence in the bottom sub-layer (BSL) vary from those in the cloud and sub-cloud layers, which together form upper sub-layer (USL). Transition in between the BSL and the USL is most pronounced in the gradient of specific humidity. The USL is characterized by weak buoyancy production in the cloud, strong anisotropy of turbulence and the scaling deviating from that predicted by Kolmogorov theory. In BSL, fluxes of buoyancy and latent heat decrease with height from the maximum at the surface down to about zero at the transition.

In general, results are consistent with the conceptual explanation of decoupling mechanism involving two separated zones of circulation and mixing: surface driven and cloud top driven. Our observations suggest that contrasting turbulence parameters need to be considered together with convection organization in order to properly quantify the vertical transport between ocean surface and stratocumulus cloud.