

Abstract

The present thesis aimed at comparison of LES (Large Eddy Simulation) numerical simulations of a stratocumulus-topped boundary layer (STBL) with in-situ measurements made by a research aircraft. Flight TO13 from the POST (Physics of Stratocumulus Top) field campaign, conducted in 2008 off the coast of California, was selected for the analysis. This case was an example of a non-classical stratocumulus cloud. Such clouds have been rarely investigated in the available literature.

The data recorded during the TO13 flight were used to characterize atmospheric conditions in and above STBL, as well as to determine the initial and boundary conditions for the numerical simulations. Results of the simulations enabled both: the assessment of the impact on the modelled cloud and STBL of selected physical phenomena (radiative cooling and wind shear near the cloud top), as well as provided a basis for the comparison to the in-situ measurements. The thesis also demonstrates the results of application of two data comparison methods: the classical, widely used methodology commonly used in the literature, and the new "virtual aircraft" method (VAM). In the latter, the computational domain of the model was sampled analogically to the way measurements are taken in the real cloud by research aircraft.

The study showed that the proposed alternative comparison method (VAM) is a useful tool for turbulence analysis. In addition, the new sampling method allowed to investigate how the flight execution strategy influences the comparison results and, thus, can be useful in future airborne campaign flight planning or as a verification of conclusions from previous campaigns. Furthermore, it was shown that by using the virtual aircraft method, it is possible to test how much the results are affected by the adopted measurement strategy. Therefore, the method can also be used for planning research flights in future field campaigns and in verification of conclusions from previous ones.

The research presented in the thesis was focused on physical processes occurring in the region of the stratocumulus cloud top. Particular emphasis was given to the inversion layer, which separates the free troposphere from the (cloud topped) boundary layer. The objective was to identify key features of the turbulence occurring in the inversion layer, as well as to identify the sources and vertical propagation of this turbulence. Thus, the thesis is a comprehensive analysis of a non-classical stratocumulus cloud case, in which the dynamical forcing for the entire boundary layer is originating mostly from the cloud top processes (radiation cooling and wind shear). The dominant cause of this situation were very low values of the surface fluxes (lower than in usually analysed cases). Moreover, TO13 flight began just before sunset. This allowed for performing analyses showing how conditions in the vicinity of the cloud top changed during boundary layer diurnal transition (from daytime STBL, to a night-time STBL).

The results indicated that in the TO13 case the boundary layer was on the verge of dynamical decoupling into two independent regions. Due to small values of both sensible and latent heat fluxes, the convective plumes were reaching condensation altitude by inertia while their further ascent was supported by water condensation heating. The main convective forcing originated from radiative cooling at the cloud top.

Other results indicated that inversion layer was in fact composed of two distinct sublayers which differ in (among other things) the properties of the turbulence present - although in both cases the observed turbulence was anisotropic (for scales above several metres). The upper region (Turbulent Inversion Sub-Layer; TISL), was located above the cloud top. It was characterised by

less developed turbulence with strongly deformed eddies. The deformation occurred due to wind shear horizontal stretching and vertical flattening by stable stratification. TISL could be extremely thin (only few metres deep) with bimodal thickness distribution. In this sub-layer turbulence, generated mostly by the wind shear, were propagated downwards. Kelvin-Helmholtz instability occurrence was also possible.

The lower region of the inversion layer (Cloud-Top Mixing Sub-Layer; CTMSL), was characterised by the well developed turbulence. The turbulent kinetic energy (TKE) propagation investigation showed the following: the cloud top originating turbulence propagated downwards, while the turbulence generated deep in the cloud propagated upwards to 50m below the cloud top where the divergence of convective circulations was noticed.