MEASUREMENTS OF TURBULENCE AT STRATOCUMULUS TOP

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Abstract Using ∼1m resolution airborne data from research flights we divide stratocumulus top region into sublayers and characterize properties of turbulence in each sublayer. Results indicate, that there are no clear differences of turbulence properties between thermodynamically different "calassical" and "non-classical" stratocumulus regimes, but there are clear signs of turbulence ainsotropy in stably stratified sublayers in the cloud top region.

RESEARCH CAMPAIGN, STATOCUMULUS REGIMES AND LAYERS AT THE CLOUD TOP

Physics of Stratocumulus Top (POST) experiment collected in-situ data on thermodynamic and dynamic properies at stratocumulus cloud top region and capping free troposphere in a series of research flights near Monterey Bay during July and August 2008. High-resolution airborne measurements were focused on a detailed study of dynamics, thermodynamics, and microphysics in order to characterize entrainment and fine structure turbulence. Details of the measurements are described in [1]. Data is freely availabe in the open database http://www.eol.ucar.edu/projects/post/ maintained by NCARs Earth observing Laboratory.

Stratocumulus clouds observed in the course of POST campaign were divided into the categories, described as "classical" and "non-classical".

- Classical cases exhibit a sharp, strong temperature inversion capping cloud top, dry air above the cloud and monotonic increase of liquid water content (LWC) from the cloud base to cloud top.
- Non-classical cases depart from this model, with more fluctuation of temperature and LWC, in particular close to the cloud top, weaker inversion and humid layer above the cloud.

From 8 cases investigated here, 3 wers calssified as "classical", 3 as "non-classical" and 2 as "intermediate". In order to study differences between the regimes in detail, [3] proposed the algorithmic division of the cloud top region into sublayers. The method identifies vertical divisions between a stable free troposphere (FT) above the cloud, a turbulent inversion sublayer (TISL) characterized by temperature inversion and wind shear, a moist cloud top mixing sublayer (CTMSL) below that, and finally a well-mixed cloud top layer (CTL). Analysis of the dynamic stability via bulk Richardson number for each of these sublayers showed stable stratification of the FT and turbulence in the other layers, with the Richardson number across TISL and CTMSL very close to its critical value. Despite differences in humidity above the cloud, inversion strength and profiles of LWC in the cloud top region, these characteristics were consistent for both "classical" and "non-classical" cases. The present study extends the preliminary analysis in [3], providing turbulence characteristics determined within each sublayer using 40Hz (1.4m resolution) data from five-hole gust probe, corrected for motion of the airplane [2].

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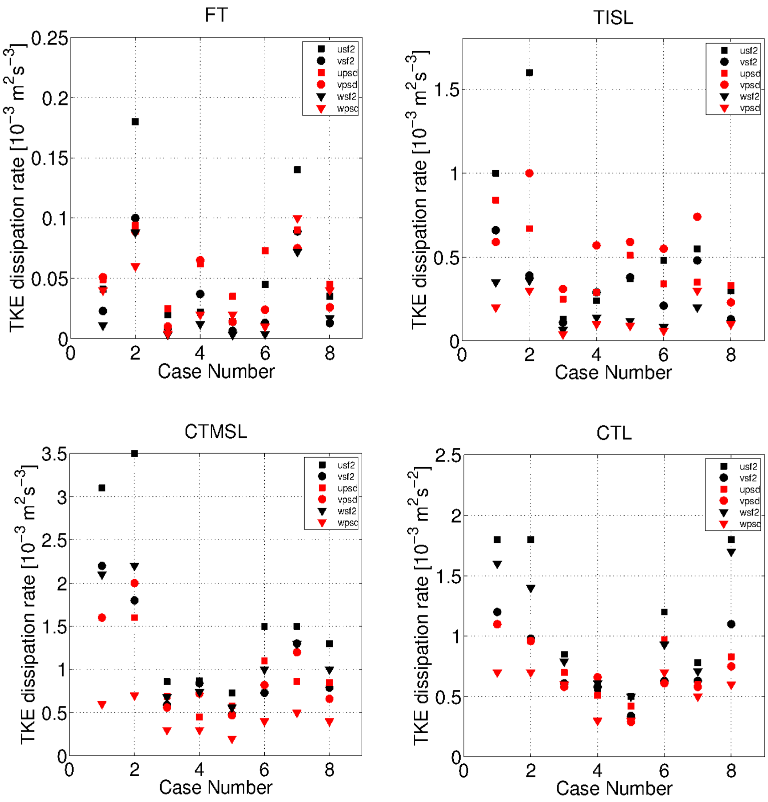
Strong horizontal wond shear and static stability in TISL and CTMSL clearly influence isotropy of turbulence. Can this be confirmed by analysis of turbulent velocity fluctuations measured in layers of the cloud top? In order to answer this question we investigated three components of velocity fluctuations (in two horizontal directions and in vertical). To estimate velocity fluctuations the average values were calculated using centered running mean over data 300 points. At 55 m/s true air speed and 40Hz sampling rate this corresponds to averaging over 412.5 m, i.e. 2-3 large eddies. On the other hand, at 1.5 m/s ascent/descent rate the averaging corresponds to 11.25 m in vertical, which allows to distinguish between the layers ∼10m deep. Sensitivity tests with averaging on 200 and 400 points indicated insignificant differences. Then the layer division was adopted to series of velocity fluctuations in order to stratify the data. Finally, we used data on velocity fluctuations on each porpoise and each layer to estimate characterictic values of TKE dissipation rates (ϵ) for each case (flight), each layer and each velocity component. To obtain more robust results, we adopted two different methods of ϵ estimation, using power spectral density (PSD) and second order structure functions (2SF). Obtained values of TKE dissipation rates are summarized in Fig. 1
Conclusions can be summarized in the following way:

- In most of the cases estimates ofϵ are consistent in a sense that maximum values are in CTMSL and spread of the results is reasonable.
- Despite the maximum shear, ϵ in TISL is significantly smaller than in CTMSL and CTL.
- Anisotropy of turbulence i.e. damping of vertical velocity fluctuations by presence of stable stratification in FT, TISL and CTMSL is reflected by smaller values of ϵ estimated from vertical fluctuations than from horizontal ones.
- There are no clear differences in ϵ values between "classical" and "non-classical" flights, i.e. cloud top entrainment instability does not directly influence ϵ at Sc top.



notice various Y scales

Figure 1. TKE dissipation rates (ϵ) estimated in 4 layers adjacent to stratocumulust top: FT (upper left panel), TISL (upper right panel), CTMSL (lower left panel) and CTL (lower right panel). Different symbols correspond to estimated from various velocity components and different methods. Cases 3, 5 and 6 are calassified as "classical", cases 2, 4 and 7 as "non classical", and cases 1 and 8 as "intermediate".

References

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