A Spectral Model for Turbulence in the Stratocumulus-topped Boundary Layer

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Abstract

A new formulation for the eddy diffusivity to be used in a stratocumulus-topped boundary-layer model is described. The parameterization is obtained by fitting experimental data from the ACE2 Experiment, and using the Taylor's theory of turbulence. It is implemented in a single-column model.

1. TURBULENCE PARAMETERIZATION

Stratocumulus formation is a very common phenomenon. This type of clouds is often present in great extensions (usually 10^6 Km^2), and lasting for a long residence time (almost half a year over Great Britain). Many experiments have been performed for understanding these type of clouds (e.g., the ACE2 Experiment (Raes, 2000)). In this study, a new parameterization for stratocumulus-topped boundary-layers is described and applied in a single-column model.

From the Taylor's theory on turbulence, Degrazia et al. (1997) have calculated the eddy diffusivity as

$$K_{aa} = \frac{\sqrt{p}}{16} s_i \, l_i \; ; \quad \text{with} \begin{cases} a = x, y, z \\ i = u, v, w \end{cases} \tag{1}$$

where s_i is the velocity variance and l_i is the wavelength of the velocity spectrum peak. Vertical variance velocity spectra were derived from the ACE2 Experiment data -

daytime stratocumulus (Brenguier et al., 2000). Measured data of l_w were modeled according to an analytic formula (Druilhet and Durand, 1997):

$$l_w = \begin{cases} Az, & z < 0.1z_i \\ Bz_i\left[1-\exp\left(-C\dfrac{z}{z_i}\right)-D\exp\left(E\dfrac{z}{z_i}\right)\right], & 0.1z_i \le z \le 0.6z_i \\ Fz_i\ \exp(-G\dfrac{z}{z_i}), & z > 0.6z_i \end{cases} \qquad (2)$$

where the coefficients are A=3.7, B=1.46, C=3.15, D=0.003, E=7.07 and G=2.7.

2. NUMERICAL EXPERIMENT AND CONCLUSIONS

The single-column model (SCM) used to test the turbulence and autoconversion schemes was proposed by Golaz (1997). The model comprises prognostic equations for the horizontal wind, the ice-liquid potential temperature, the total water mixing ratio, and the turbulent kinetic energy.

The SCM with the new parameterizations was used to simulate a one ACE2-CLOUDYCOLUMN case. The day at 08 July 1997 larger droplet concentrations occurred (196 cm^{-3}, on average) – see Almeida et al. (2002). Figure 1 depicts the time evolution of the vertical profile of the cloud water content. Figure 2 shows modeled field results against observations, where a good agreement is seen.

The turbulence scheme was implemented and tested in a SCM, where a parameterization based on the measured spectrum of vertical velocity variance to represent the turbulent transport in diurnal stratocumulus-topped boundary-layers is employed. Results were compared with observation of the CLOUDYCOLUMN, and it is seem that prediction agreed well with ACE2 observations. The SCM can be useful in predicting the evolution of stratiform cloud and the role of different physical processes in the evolution of stratocumulus-topped boundary layers.

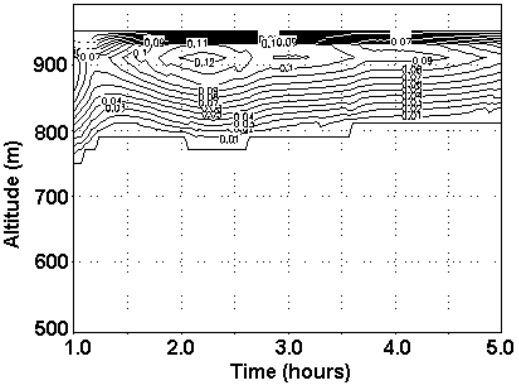
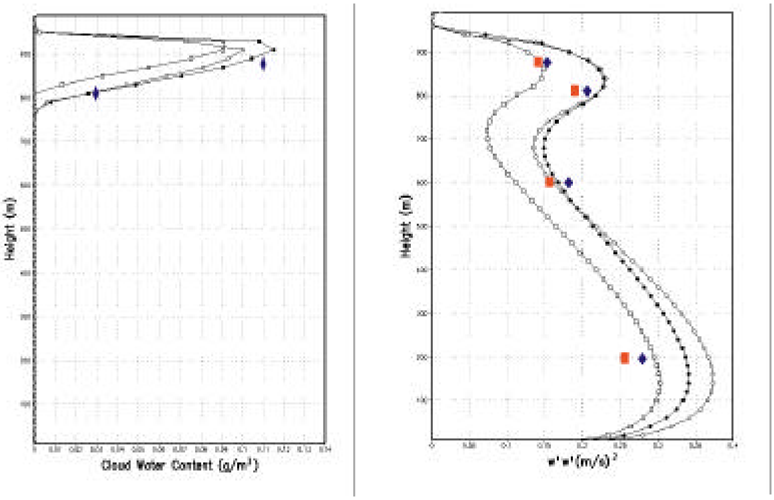


Figure 1 – Time evolution of the vertical distribution of the cloud water content (g/m^3).



(a) (b)

Figure 2 – Diamonds represent observed values, squares correspond to filtered values: (a) Hour average of the simulated cloud water; (b) Simulated profile of the vertical velocity variance, 2nd hour (white circles), 3rd hour (white square), and 4th hour (black circle).

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