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# DIURNAL CYCLES OF A MARINE SC LAYER AND CU OVER LAND SIMULATED WITH A TKE SCHEME USING A UNIFIED FORMULATION OF THE MIXING LENGTH

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## 1 INTRODUCTION

The representation of the cloudy boundary layer (CBL) using single column models (SCM) is a complex subject, but of permanent interest, since it is the previous step to the implementation of theories in NWP or climate models. The CBL is of outmost importance, since it determines the radiative budget of the atmosphere and the transport of energy and mass from the surface to the free troposphere. Very different cloudy situations need to be modelled, ranging from complete coverage (Stratocumulus cloud topped boundary layers (STBL)), to low shallow cumulus topped boundary layers (CTBL). Both extreme situations are controlled by different physical processes. STBL is domained by radiative cooling at cloud layer top, mixing the whole boundary layer from conservative variables ($\theta_l$ and $r_t$) values. CTBL has a clear convective structure, where updrafts generate condensation in a conditionally unstable layer, and with compensating dry downdrafts. Cumulus in different stages of its life cycle coexist in that layer. Traditionally, high-order turbulence closures have been used to parameterize STBLs, while mass-flux schemes have been used to represent CTBLs. Many efforts have been made looking for a unified representation of boundary layer clouds, mainly trying to extend mass flux ideas to represent also stratocumulus layers ( Lappen and Randall(2001)). De Roode *et al.* (2000), pointed from theoretical arguments that some degree of equivalence is shown between entrainment/detrainment rates in a mass flux scheme and mixing length in a turbulence-closure scheme. This work presents a study of how well a 1.5 order closure turbulence scheme can do for both CTBL and STBL. Ther are two key factors: a statistical subgrid condensation (Sommeria+Deardorff (1977) with low cloudy conditions correction), and the closure of the scheme with Bougeault-Lacarrère (1989) mixing length (BL89).

## 2 MIXING LENGTH INCLUDING CLOUDINESS

BL89 mixing length is obtained as follows:

$$\int_{z}^{z+l_{up}} \beta(\theta_{v,p}(z') - \theta_{v,e}(z'))dz' = e(z) \qquad (1)$$

$$\int_{z-l_{down}}^{z} \beta(\theta_{v,p}(z') - \theta_{v,e}(z'))dz' = e(z) \qquad (2)$$

where $\beta = g/\theta_{vref}$, and $p$ and $e$ denote parcel and environmental values. Mixing length $L$ is obtained averaging $l_{up}$ and $l_{down}$. For dry situations, initial $\theta_{v,p}(z)$ is conserved ($\theta_{v,dry} \equiv \theta_{v,p}$). In total cloud coverage conditions, conservation of $\theta_l$ and $r_t$ to obtain the buoyancy of parcel at each level is requiered ($\theta_{v,wet}(z') \equiv \theta_{v,p}(z')$). In a partially cloudy layer, this approach makes the displaced particle too active, leading to too high cloud cover. The following expression for the buoyancy of the particle is proposed for cloud cover between 0 and 1, reducing to the previous proposals for extreme cases:

$$\theta_v(z') = N \cdot \theta_{v,wet}(z') + (1 - N) \cdot \theta_{v,dry}(z') \qquad (3)$$

After some calculations, we have

$$\theta_v(z') = \theta_{v,wet}(z') - (1 - N)(\theta_{v,wet}(z') - \theta_{v,dry}(z')) \qquad (4)$$

that is, final $\theta_v$ can be expressed as wet value minus some term proportional to difference between wet and dry values. The use of N as a weighting factor in equations (3-4) has physical sense and also relates somewhat to mass-flux top hat sampling. Nevertheless, some other factors can play an important role in the computation of a final $\theta_v$, like cloud core (which would account for only active clouds), or skewness (to consider the assimetry of updrafts and downdrafts) and so they could be considered.

## 3 CASE TESTS: DIURNAL CYCLES OF SC AND CU

To test this ideas, the two boundary layer simulations from European EUROCS [1] project are used. Two diurnal cycle cases were proposed:

- a) Stratocumulus case based on California FIRE observations campaign. Simulation lasts for 37 hours, showing a clear diurnal cycle.
- b) Shallow cumulus diurnal cycle over land, from ARM campaing (measurements made at Southern Great Planes). Simulations lasts 14.5 hours

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[1] EUROCS: European Cloud Systems: http://www.cnrm.meteo.fr/gcss/EUROCS/EUROCS.html

We use Meso-NH model (Lafore et al, 2000), both in SCM and in LES, except when opposite stated.

## 4 RESULTS

**FIRE case** In Cuxart and Sánchez (1997) the wet mixing length was tested in a stationary case. Now this parameterization is checked in an evolving situation. Fig. 1 shows the evolution of the liquid water path, and the improvement of wet length related to dry one when comparing with LES results.

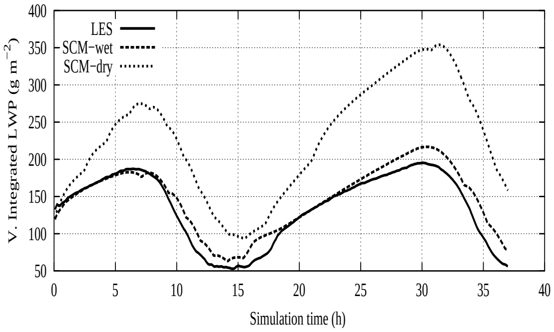

Figure 1: Integrated LWP, FIRE case

Buoyancy fluxes (fig. 2) gives an accurate description of how SCM behaves compared with LES, and the reasonable representation of the most important physical processes in a STBL (phase change and entrainment at cloud top). The use of a mixing length that takes into account the phase changes in the evolution of the displaced particle means a clear improvement when simulating the diurnal cycle of a STBL.

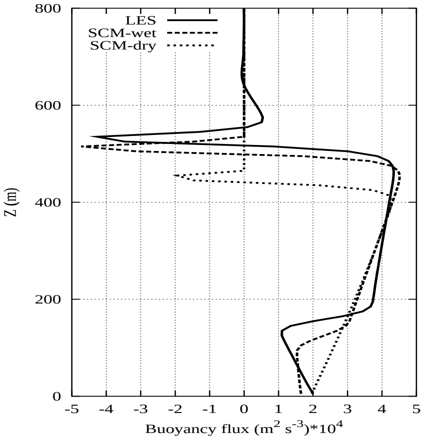

Figure 2: $\overline{w'\theta_v'}$ flux, night conditions

**ARM case:** Timeseries of LWP and TKE (fig. 3) show clearly the difficulty of a correct representation of the whole cycle in intensity and time location: only with a "mixed" formulation (eq. 3-4) of L the whole cycle can be reasonably reproduced. Inspection of the vertical structures shows that cloud tops (with cloud cover less than 3%) are not captured properly and the vertical distribution of cloud water is not as steady as LES, but follows a cycle. Turbulent fluxes and related quantities have realistic integral values and vertical structure, but they clearly understimate mean cloud layer growth, showing a shallower mean turbulence vertical activity. If more weight is given to the wet contribution the cloud layer is deeper, but with too high values for cloud cover and cloud water. The adequate combination of factors is still under research.

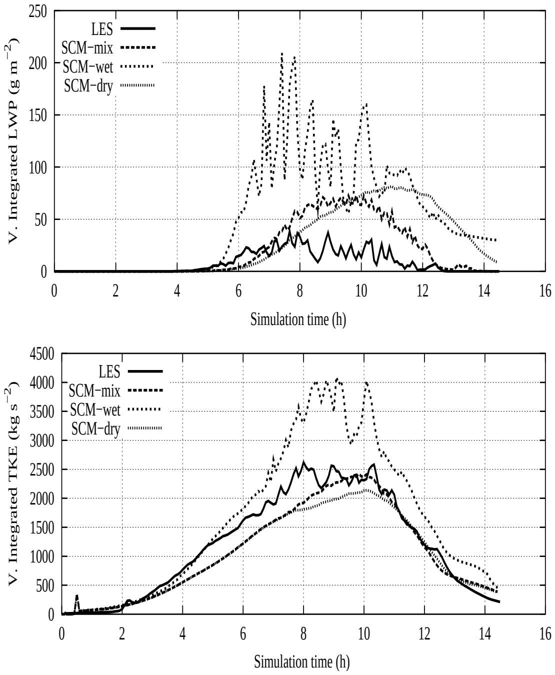

Figure 3: LWP and TKE, ARM case

## 5 CONCLUSIONS

Results of FIRE case confirm that the good behaviour under stationary conditions (Cuxart,Sanchez (1997)) can be reasonably reproduced by a 1.5 turbulence closure model with a mixing length that takes into account condensation procesess. For cumulus conditions, an intermediate formulation between dry and completely wet conditions improves both extreme formulations. But although diurnal cycle and the fluxes are qualitative captured and conditional instability is preserved, vertical distribution of cloud activity is understimated with mixed formulation. Further work is being done, trying to obtain a complete consistency in the use of N as factor to weight mixing length formulation.

**References** :

-Bougeault,Lacarrère,1989:*Mon.Wea.Rev.***117**,1872-1890

-Cuxart,Sanchez,1997:12$^{th}$ Symposium on Boundary layers and turbulence, pp 261-263

-de Roode,Duynkerke,Siebesma,2000:*J.Atmos.Sci.***57**, 1585-1598

-Lappen,Randall,2001:*J.Atmos.Sci.***58**, 2052-2072

-Sommeria,Deardorff, 1977: *J.Atmos.Sci* **34**,344-355