**P4.11**

# LARGE-EDDY SIMULATIONS OF STABLE BOUNDARY LAYER: EXPLORATION OF RANGES OF APPLICABILITY

M.A. Jiménez [(1)]*, and J. Cuxart [(2)]

(1) Instituto Nacional de Meteorología, Spain

(2) Grup de Meteorologia, Dpt. Fisica, Universitat de les Illes Balears, Spain

## 1 INTRODUCTION

The Stably stratified atmospheric Boundary Layer (SBL) developes during clear sky nights with weak wind. It is relatively shallow (at most some hundreds of meters), and in mid-latitudes, it is short-lived and with complicated dynamics due to the predominance of the local topographic effects. The two major factors determining the behaviour of the SBL are the surface cooling rate and the wind speed. Several phenomena characteristical of the SBL and very frequently observed are the low-level jet, internal gravity waves and intermittent turbulence.

Large-eddy simulations (LES) of the Atmospheric Boundary Layer have become a usual and powerful suplement to experimental work. However, in the case of the SBL, the small scale of the most energetic structures (resolved explicitly by the model) imposes a high spatial resolution and has a critical dependency on the subgrid-scale model, since under very stable stratification, the grid mesh can be larger than the most energetic eddies and the assumption of isotropy is no longer valid.

In this work, a number of LES will be performed at a fixed resolution, varying the surface cooling rate and the wind, in order to inspect the range of applicability of the method for the SBL. Failures will be searched, through the intercomparison with some parameters of the observational campaign SABLES 98 (Cuxart et al, 2000).

## 2 MODEL SETUP AND SIMULATION STRATEGY

LES have been made using the Meso-NH nonhydrostatic model (Lafore et al.,1998). The domain considered in the simulations is 400m×600m×1500m with 96×96×130 grid points. The vertical resolution changes with height: constant (5.21m) from surface to 500m and decreasing with height from 500m to 1500m. The main phenomena of the SBL, taking normally place below 500m, can be captured. The layer above allows to have realistic upper boundary conditions.

A geostrophic balance is imposed and the surface roughness is taken constant (0.1m). The Monin-Obukhov similarity theory has been applied.

The SBL LES starts from a steady neutral state, with the same conditions described above. It has been obtained running 100.000s of simulation, time when the fields are stationary and the turbulence is developed. Three different cases of steady neutral state were considered, depending on geostrophic balances: $(u_g, v_g)$ = (10,0) $m\,s^{-1}$, (8,0)$m\,s^{-1}$ and (5,0)$m\,s^{-1}$.

To perform the SBL simulation, after those 100.000s, constant surface temperature flux of values ($< w'\theta' >_s$ = -0.005, -0.010, -0.025,- 0.050 $K\,m\,s^{-1}$) have been applied consecutively as lower condition every two hours. The total SBL integration is eight hours. The LES statistics are computed during the last hour of each two-hours simulation.

## 3 MODEL RESULTS

A total of 15 runs are compared (including neutral case) for each cooling rate and prescribed geostrophic wind.

The effect of increasing the cooling surface flux produces important changes in the mean temperature and wind fields. When the cooling surface flux increases (at a given geostrophic wind) the stratification increases, as it is shown in figure 1. In the case of very strong cooling rate (-0.05 $K\,ms^{-1}$) the stratification is very strong and most likely the simulation becomes unrealistic. For all the cases with a fixed wind, the height of the SBL remains constant, just changing the strength of the inversion. On the other hand, for different prescribed geostrophic winds, the height of the SBL changes, being higher for stronger wind speeds (not shown).The mean wind profiles show a maximum just above the stratified layer for strong cooling rates, more intense as the stratification increases.

An important magnitude to study turbulent processes is the Turbulent Kinetic Energy (TKE). In LES the total TKE is the sum of the energy of the resolved and subgrid motions (given by the subgrid-scale model). We use the percentage of the subgrid energy to the total as a parameter indicating the goodness of a particular LES. The subgrid-scale scheme is supposed to explain more energy as the stratification increases and the wind decreases. Table 1 shows that this behaviour is observed for most of the simulations, except for very strong cooling rate or very weak wind,

*Corresponding author address: Maria Antónia Jiménez, Instituto Nacional de Meteorología,Apt. 285, 28071, Madrid, Spain, pni@inm.es

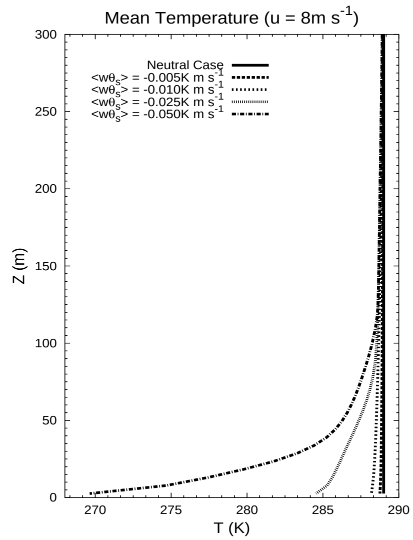


Figure 1: Mean Temperature profile

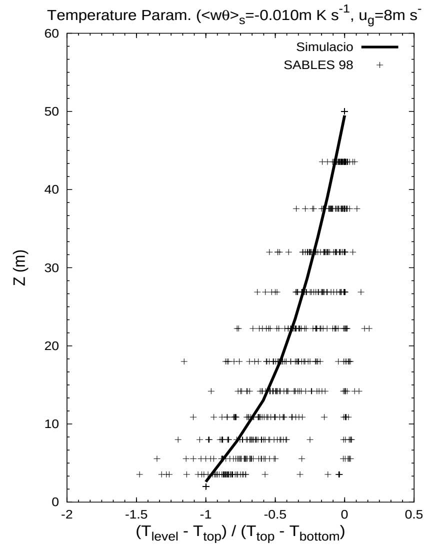


Figure 2: Temperature parameter

when this criteria is not fulfilled (in bold). The subgrid scheme fails in those cases. The case in italics is doubtful, since the percentage is high but does not increase as the other cases.

| | $5ms^{-1}$ | $8ms^{-1}$ | $10ms^{-1}$ |
|---|---|---|---|
| Neutral | 12.20 | 10.31 | 9.63 |
| 0.005 $mKs^{-1}$ | 19.59 | 15.44 | 13.13 |
| 0.010 $mKs^{-1}$ | **13.55** | 20.57 | 15.84 |
| 0.025 $mKs^{-1}$ | **6.19** | *20.83* | 21.88 |
| 0.050 $mKs^{-1}$ | **4.41** | **3.82** | **12.15** |

Table 1: V.I.of $TKE_{subgrid}$ divided $TKE_{total}$ (%)

## 4 COMPARISON TO SABLES 98 DATA

Some parameters have been computed out of the LES and compared to their equivalents out of the 100 meter tower setup during the SABLES 98 experimental campaign (10-28 sept 98). 30-min averages are used and 253 values of the 327 available are in the range of our simulations (81%).

In table 2 the number of events observed for each simulation range is shown. The percentage indicates the proportion of the instants related to observed instants with the simulation ranges. In bold there are the cases that the simulation is not realistic at all because the model has collapsed. Simulations reproduce approximately 50% of cases observed in SABLES campaign and 65% of the range of the table. To inspect how well behaved are the simulations, the following parameters are used, normalised by the surface values: TKE, increment of temperature, vertical and horizontal heat fluxes.

In general, the temperature and horizontal flux parameters experimental data fit well with the simulations (e.g. figure 2). But for the vertical heat flux and TKE parameters data shows a large scatter whereas the simulations show a very consistent pattern for all the explored range. The scatter in the data might be explained by the presence of many coherent structures, including low-level jets and gravity waves. LES however reproduce adequately the statistics from the horizontal motions. Some of the collapsed LES (bold in table II), can give good values of the computed parameters, indicating that the resolved motions tend to supplement the bad behaviour of the subgrid scale scheme under very strong stratification.

| | $5ms^{-1}$ | $8ms^{-1}$ | $10ms^{-1}$ |
|---|---|---|---|
| Neutral | 4.0 | 2.8 | 0.4 |
| 0.005 $mKs^{-1}$ | 7.9 | 6.3 | 1.6 |
| 0.010 $mKs^{-1}$ | **18.6** | 20.2 | 5.5 |
| 0.025 $mKs^{-1}$ | **2.8** | *15.0* | 13.4 |
| 0.050 $mKs^{-1}$ | **0.0** | **0.8** | **0.8** |

Table 2: Number of observed events (%)

## 5 CONCLUSIONS

The LES simulations of SBL within the selected ranges of cooling surface flux and geostrophic wind are realistic and very well compared to experimental data (SABLES 98 campaign) in more than half of the available observed data at an average resolution of 5 meters. So, LES of the SBL is possible with a standard LES code, provided that the stratification is not very strong. The model collapse is defined through the failure of the subgrid-scale scheme to account for the unresolved motions.

**References**

Cuxart et al.,2000. *Bound.-Lay. Met.* **96**, 337-370.
Lafore et al., 1998. *Ann. Geoph.* **16**, 90-109.