NEAR SURFACE TURBULENCE IN A NEUTRAL PLANETARY BOUNDARY LAYER: COMPARISON OF LES WITH THE CASES'99 EXPERIMENT OBSERVATIONS

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Summary
This work compares the results of the field experiment CASES'99 (in a neutral atmosphere) with an idealized LES simulation performed with Méso-NH. Energy profiles and flow patterns of the real case and the LES are compared, showing a good agreement. In particular, the LES shows the formation of near-surface streaks spaced of approximately 390 m, in agreement with high resolution Doppler lidar radial velocity recorded in CASES'99, which shows evidence of an approximate spacing of the streaks of 315 m.

INTRODUCTION

The turbulence structure and its spectral characteristics in the neutral surface layer (SL) has been the subject of considerable research effort for the last decades, since turbulence is one major process controlling energy and matter exchanges between the surface and the planetary boundary layer (PBL).

At present, most of the effort is focused on (i) understanding the dynamical processes that contribute to the turbulent surface fluxes, and particularly the role of turbulent eddies; (ii) deriving reliable and accurate parametrizations of atmospheric surface turbulence, from large-eddy simulations (LES) to general circulation models (GCM). Indeed, in atmospheric modelling, most of the turbulent processes occur at sub-grid scale and are thus not explicitly resolved by numerical models. The resolved scales are assumed to contain most of the energy of turbulent motion whilst on subgrid scales, motions are the less energetic. This approach works well far from regions of large gradients, whereas subgrid contribution may become larger than the resolved part near the surface. Consequently, model results become more sensitive to the subgrid scheme in this region.

The issue of this paper is to evaluate how a LES performs in retrieving the near-surface turbulence properties in terms of organized eddies and their related energetics. To do so, simulated fields of highly resolved LES of a neutrally stratified surface layer are compared with the near-surface data collected during the CASES'99 experiment.

DATA SETS

The CASES'99 experiment

The CASES'99 experiment was designed to be a nighttime experiment to study the stable boundary layer and to study physical processes associated with the morning and evening transition periods (Poulos et al. 2002). The experimental period was from 1 to 31 October 1999 near Leon 50 km east of Wichita, Kansas.

The current study uses data collected on the 13 October 1999 near-neutral case from six 10-m and one 60-m meteorological towers, radiosonde releases and the High-Resolution Doppler Lidar (HRDL) developed by NOAA/ETL in cooperation with the NCAR/ATD and ARO (Grund et al., 2001).

LES model and simulation

The large-eddy simulations presented have been made using Méso-NH (Lafore et al., 1998). In this paper, it is used exclusively in its LES mode.

A neutrally-stratified, midlatitude, barotropic, dry atmosphere PBL flow was simulated with forcing similar to the near-neutral surface layer case documented in the framework of the CASES'99 experiment (Drobinski et al., 2003). The simulations were made on a domain 3 km long, 1 km wide and 750 m high with 6.25 m grid resolution (Carlotti, 2002). The computing grid is cubic to avoid any influence of anisotropy of the grid with periodic boundary conditions on the lateral sides and a rigid lid at the top.

The initial condition was a laminar geostrophic flow $U_g = 10$ m.s^{-1} aligned along the x-axis with small random temperature perturbations to generate turbulence. The surface buoyancy flux is zero and the surface friction velocity is constant ($u_* = 0.42$ m.s^{-1}). Table 1 compares the mean and turbulence variables used to force the LES dynamics and the corresponding values obtained from the CASES'99 measurements (radiosounding and sonic anemometer).

A relatively deep logarithmic surface wind profile formed with no veering up to 40 m. The surface roughness length is about 0.04 m.

COMPARAISON OF LES WITH OBSERVATIONS

The LES results show a good agreement with the observations collected between the surface and about 100 m. The variables that we compared with the observations are the vertical profile of wind velocity, of the variances of the three

components of the wind, of the turbulent kinetic energy flux and of the momentum fluxes. For example, Figure 1 shows the comparison of the vertical profiles of the longitudinal and transverse velocity fluctuation variances retrieved from Méso-NH (dashed line) and from the radial velocities obtained with HRDL (solid line). The overall profile is satisfactorily simulated with nearly constant variances up to about 30 m and decreasing variances above. In the upper levels, Méso-NH slightly underestimates the variances.

In addition to the vertical profiles, LES flow visualization shows a characteristic near-surface streak spacing of approximately 390 m oriented at 8^o from the geostrophic wind and aligned with the surface wind, in good agreement with HRDL radial velocity horizontal field which shows evidence of 315 m horizontally spaced streaks (Figure 2). The simulated and observed finescale streaks extend up to 50 m above the ground.

References

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Table 1: Mean and turbulence variable retrieved from Méso-NH and the observations

Variable	LES	CASES'99
u_* (m/s)	0.42	0.4
U_g (m/s)	10	8-10
z_0 (m)	0.04	0.04
z_i (m)	750	700-750

Figure 1 : Vertical profiles of the streamwise (a) and spanwise (b) wind component fluctuation variances from the Méso-NH simulations (dashed line) and the Doppler lidar (solid line).

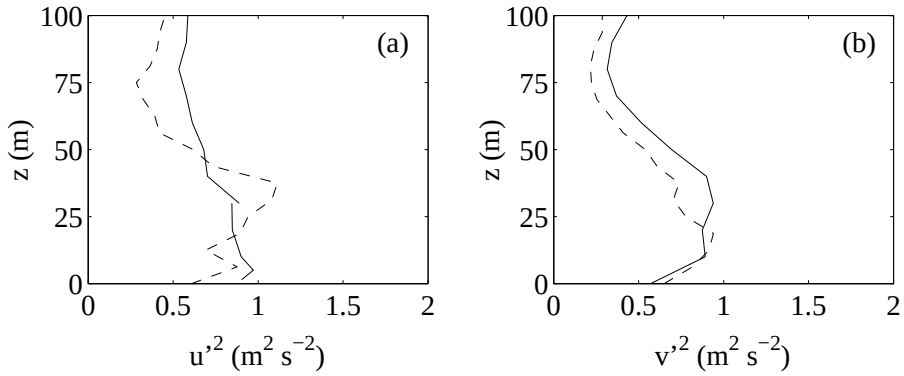

Figure 2 : (a) Snapshot of the streamwise velocity fluctuations found in the LES; (b) HRDL radial velocity field.