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LARGE-EDDY SIMULATION OF STABLY STRATIFIED CANOPY TURBULENCE

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1. INTRODUCTION

Annual net ecosystem carbon exchange results from a small difference between large seasonal plant uptake and respiration. Nighttime and cold season fluxes are difficult to measure due to the spatial and temporal intermittency of stable boundary layers (*e.g.,* Wilson, 2002) and small vertical gradients resulting from canopy-enhanced mixing (*e.g.,* Baldocchi, 2003).

There have been a number of investigations of the stably stratified PBL using large-eddy simulation (LES) (*e.g.,* Saiki et al., 2000, Kosovic and Curry, 2000, Beare, 2004). Although, these studies found LES promising as a tool to investigate weakly stable atmospheres, stable stratification tends to reduce turbulence length scales. When using LES to investigate stably stratified environments this length scale reduction places tremendous reliance on the subgrid model especially near the ground, where the length scales are further limited by the presence of the rigid surface.

In a canopy a fixed length scale is imposed on the turbulent flow and the important sink for momentum is elevated above the surface. This lessens the importance of the interactions with the underlying surface making it feasible to use LES. In this presentation we'll use a set of large-eddy simulations to investigate stability influences on turbulent exchange within and above vegetation.

2. NUMERICAL METHODS

For this study we use the NCAR-LES originally described in (Sullivan et al., 1996). We employ the Sullivan et al.'s (1996) anisotropic subgrid-scale model to represent unresolved fluxes. Boundary conditions are periodic in the horizontal, (Klemp and Durran, 1983) at the top of the domain, and a drag law is asssumed between the lowest model level and the ground surface to determine the momentum flux at the ground.

For the with-canopy cases, we include a term in the Navier-Stokes equations representing the drag imposed by the forest canopy which is written as

$$F_i = -C_d a U \overline{u}_i \,. \quad (1)$$

Where, C_d is an isotropic drag coefficient, a is leaf area density (one-sided leaf area per unit volume), and U represents the current wind speed, $(\overline{u}_i\overline{u}_i)^{\frac{1}{2}}$. Following (Brown and Covey, 1966), the canopy also is a source or sink of heat based on the distribution of plant matter.

3. SIMULATIONS

Four simulations will be compared and contrasted; two sets of two cases. The first set of two runs simulates a weakly unstable planetary boundary layer; one run without plants, and one with an LAI=2 canopy. The second set of two runs is of a stably stratified planetary boundary layer; one without plants, and one with a canopy of LAI=2. These four simulations will establish the vital differences in turbulence structure arrising from the varying buoyant forcing and modifications induced by vegetation.

The unstable cases contain a mix of shear and buoyant production of turbulence. The geostrophic wind is specified as (U_g, V_g) = (5, 0) m s^{-1}. The total input of heat to the flow is fixed at 25 W m^{-2}. For the no-canopy case, this source is at the ground. For the with-canopy case, this source is distributed through the depth of the canopy and there is no source of heat from the ground. These simulations are performed on (600, 600, 400) grid points representing (3, 3, 1) km in the (x, y, z) directions. Therefore, the resolution throughout the entire PBL is (4, 4, 2.5) m. In the with-canopy case, the canopy is 25 m tall and resides in the lowest ten grid points, is horizontally homogeneous, and the plant area density distribution is similar to a deciduous forest with a relatively dense overstory a top a relatively open trunk space.

The stably stratified cases mimic those in (Beare, 2004). The geostrophic wind (U_g, V_g) is (8, 0) m s^{-1}. In the no-canopy case, the surface temperature is cooled at a fixed rate of 0.25 K hr^{-1}, which corresponds to surface heat flux of about -12 W m^{-2}. In the with-canopy case, we impose a total flux of heat to the canopy of -12 W m^{-2}, which is distributed through the depth of the canopy. These simulations use (500, 500, 400) grid

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points representing (1, 1, 0.4) km. Therefore, the resolution through the entire PBL is (2, 2, 1) m. In the with-canopy case, the canopy is also horizontally homogeneous and 25 m tall, but it is resolved vertically by 25 grid points.

4. RESULTS

Results will be presented on 1) the ability of LES to simulate stably-stratified canopy turbulence, 2) important modifications induced by the canopy, and 3) characteristics of the turbulence structure.

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