J2.4 LES SIMULATION OF TURBULENT FLOW WITHIN AND ABOVE A VEGETATION CANOPY USING NON-LINEAR SUBGRID-SCALE PARAMETERIZATION

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1. INTRODUCTION

Turbulence drives the atmosphere-plant canopy exchanges of heat, water vapor, CO_2 and a host of other scalar quantities. Large-eddy simulation (LES) has proven to be a valuable tool to enhance understanding of canopy turbulence and atmospheric exchange. We will use a LES model with nonlinear parameterization of subgrid-scale variables to simulate turbulent flow structure under neutral and stable stratified conditions. A brief introduction about this LES model is given including the governing equations, numerical methods, initial and boundary conditions and non-linear subgrid-scale parameterization. The next step will include studying the boundary layer structure within and over a vegetation canopy by changing the boundary conditions and surface conditions.

2. GOVERNING EQUATIONS

The incompressible Navier-Stokes equations can be expressed as

$$\frac{\partial \bar{u}}{\partial t} = \bar{v}\bar{\zeta}_z - \bar{w}\bar{\zeta}_y + f\bar{v} - \frac{\partial P^*}{\partial x} - \frac{\partial < \bar{p} >}{\partial x} - \frac{\partial \tau_{xy}}{\partial x} - \frac{\partial \tau_{xy}}{\partial y} - \frac{\partial \tau_{xz}}{\partial z} \quad (1)$$

$$\frac{\partial \bar{v}}{\partial t} = \bar{w}\bar{\zeta}_x - \bar{u}\bar{\zeta}_z - f\bar{u} - \frac{\partial P^*}{\partial y} - \frac{\partial < \bar{p} >}{\partial y} - \frac{\partial \tau_{xy}}{\partial x} - \frac{\partial \tau_{yy}}{\partial y} - \frac{\partial \tau_{yz}}{\partial z} \quad (2)$$

$$\frac{\partial \bar{w}}{\partial t} = \bar{u}\bar{\zeta}_y - \bar{v}\bar{\zeta}_x + \frac{g\bar{\theta}}{\theta_0} - \frac{\partial P^*}{\partial z} - \frac{\partial \tau_{xz}}{\partial x} - \frac{\partial \tau_{yz}}{\partial y} - \frac{\partial \tau_{zz}}{\partial z} - < \bar{u}\bar{\zeta}_y - \bar{v}\bar{\zeta}_x + \frac{g\bar{\theta}}{\theta_0} \quad (3)$$
$$- \frac{\partial P^*}{\partial z} - \frac{\partial \tau_{xz}}{\partial x} - \frac{\partial \tau_{yz}}{\partial y} - \frac{\partial \tau_{zz}}{\partial z} >$$

Here the angular brackets denote horizontal means; *f* is the Coriolis parameter, $\zeta_x, \zeta_y, \zeta_z$, is the vorticity components in *x, y* and *z* direction, and τ are the subgrid-scale (SGS) Reynolds stresses. The continuity equations becomes

$$\frac{\partial \bar{u}}{\partial x} + \frac{\partial \bar{v}}{\partial y} + \frac{\partial \bar{w}}{\partial z} = 0 (4)$$

The equation for a filtered conserved thermodynamic variables can be shown as

$$\frac{\partial \bar{\theta}}{\partial t} = -\bar{u}\frac{\partial \bar{\theta}}{\partial x} - \bar{v}\frac{\partial \bar{\theta}}{\partial y} - \bar{w}\frac{\partial \bar{\theta}}{\partial z} - \frac{\partial \tau_{\theta x}}{\partial x} - \frac{\partial \tau_{\theta y}}{\partial y} - \frac{\partial \tau_{\theta z}}{\partial z} (5)$$

Where τ_θ is the subgrid turbulence fluxes of virtual potential temperature.

3. NUMERICAL SCHEMES

A mixed scheme of Fourier expansion in the horizontal directions and finite differencing in the vertical is used in this model.

The pseudospectral method is chosen to evaluate the horizontal derivatives, and for the vertical derivatives, a centered finite-differences of second-order accuracy are used in this model.

The pressure field $\bar{p}$ is solved by taking the divergence of the equations of motion, and combining with the continuity equations to form a Poisson equation.

4. SUBGRID-SCALE PARAMETERIZATION

A backscatter SGS method is used, following Kosović(1997) and Kosović and Curry (2000). This includes a backscatter parameter whose values depends on such issues as the where the cut-off wavenumber falls.

5. REFERENCES

Kosović, B. and Curry, J.A., 2000. A large-eddy simulation study of a quasi-steady stably-stratified atmospheric boundary layer. *J. Atmos. Sci.* 57: 1052-1068.

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