THIRD-ORDER MOMENT CLOSURE THROUGH A MASS-FLUX APPROACH

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Abstract. The parameterization of the third moments, the flux of the heat flux and the flux of the potential temperature variance, is considered. It is shown that present parameterizations of these moments using the mass-flux approach with a 'top-hat' profile assumption lead to a significant underestimation, resulting in an inaccurate representation of second moments in the convective boundary layer. It is also shown that the underestimation is a result of the 'top-hat' profile assumption in which the sub-plume contributions to the total fluxes are ignored. By including these contributions a new parameterization is proposed, which satisfies the physical requirements of symmetry and realizability, and gives results that are in fair agreement with the large-eddy simulation data.

Keywords: Third-order moments, Convective boundary layer, Mass-flux approach, Parameterization.

1. Introduction

As demonstrated repeatedly through observation (Lenschow et al., 1980) and through large-eddy simulation (LES) studies (Moeng, 1984) the motions in the convective atmospheric boundary layer (CABL) produce turbulent mixing that is essentially nonlocal in nature, resulting from the presence of large-scale semi-organized coherent structures. Therefore, it has become clearly evident that, when applied to the CABL, the traditional down-gradient closures for second-order and third-order moments fail to capture the complex transport processes, including counter-gradient and entrainment effects, which affect the profiles of the mean quantities. As pointed out by Abdella and McFarlane (1997; hereafter AM97) and others (Zilitinkevich et al., 1999), in order to properly include the nonlocal. integral properties of the boundary layer, one needs to accurately represent the third-order turbulence moments that are primarily responsible for the nonlocal transport of turbulence fluxes and variances.

Many researchers have recognized the importance of accounting for these nonlocal and counter-gradient effects in the CAB L, and this has led to a great deal of research interest in higher-order closures, including the AM97 second-order turbulence scheme that incorporates a nonlocal eddy diffusivity and counter-gradient

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