FLUID PARTICLE MOTION IN INHOMOGENEOUS AND NON-GAUSSIAN TURBULENCE

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INTRODUCTION

It has been proven that modelling turbulent dispersion in the Lagrangian framework is a successful and flexible approach. The effects of inhomogeneity, instationarity and non-Gaussianity of turbulence have to be taken into account (Thomson, 1987; Sawford, 1991) and there are questions concerning the modelling of buoyancy (van Dop, 1991) and chemical reactions. As shown recently (Heinz and Schaller, 1993), equations for particle motion, particle potential temperature and mass fractions of chemical components can be determined completely consistent with the exact ones for the means and variances, assuming the approximations of Kolmogorov and Rotta. Moreover, the influence of non-linear terms to the systematic particle motion is discussed for locally Gaussian-distributed fluctuations. However, there arises the question in which extent the consistence with the exact transport equations for the first and second moments determines particle motion, which influence arises from non-Gaussian distributed fluctuations for instance for transport coefficients like the diffusion coefficient or the Lagrangian timescale. To get more insight in the contributions of non-Gaussianity and inhomogeneity transport coefficients are calculated here for different non-Gaussian distributed vertical velocity fluctuations coinciding in it means and variances.

DIFFUSION COEFFICIENT

Assuming according to Kolmogorov theory $B^{ij} = 1/2\ C_0 <\varepsilon> \delta_{ij}$, where $<\varepsilon>$ is the ensemble-average rate of dissipation of energy and C_0 a universal constant, and gradients of the mean wind and potential temperature field limited by the scaling of the corresponding fluxes the symmetric component K_s of the 3-dimensional diffusion coefficient matrix is given by (Heinz, 1990) $K_s = <V^2> B^{-1}$, V being completely determined by the Eulerian velocity distribution function g_E. For the latter a two-mode model is considered, $g_E = g_G\ g^3/g_G^3$, g_G being a 3-dimensional Gaussian distribution function, g_G^3 the Gaussian distribution of vertical fluctuations and g^3 is given by

$$g^3 = \frac{a_-}{(2\pi)^{1/2}\sigma_-}\exp\left\{-\frac{(w+w_-)^2}{2\sigma_-^{\,2}}\right\} + \frac{a_+}{(2\pi)^{1/2}\sigma_+}\exp\left\{-\frac{(w-w_+)^2}{2\sigma_+^{\,2}}\right\},$$

where it is assumed for simplicity $w_+ = \sigma_+$, $w_- = \sigma_-$, and $\gamma = \sigma_+ / \sigma_-$ as measure of inhomogeneity (w being the vertical velocity). Hence, all parameters are given in dependence on γ, $a_+ = (1+\gamma)^{-1}$, $a_- = \gamma\ (1+\gamma)^{-1}$, $\sigma_+^{\,2} = \langle w^2\rangle\ \gamma\ /2$, $\sigma_-^{\,2} = \langle w^2\rangle\ \gamma^{-1}\ /2$, ensuring that the distribution function has a mean equals zero and a variance equals $\langle w^2\rangle$. Then, the diffusion coefficient can be calculated by $K_s = B^{-1}\, V^2\, \Gamma$, where V being the matrix of the second moments of the velocity distribution function and Γ a matrix depending on γ only and representing the influence of non-Gaussianity. Moreover, the skewness $s^3 = \langle w^3\rangle / \langle w^2\rangle^{3/2}$ and the curtosis Ku $= \langle w^4\rangle / \langle w^2\rangle^2$ are simple related by γ, so that the latter can be calculated from the skewness and the curtosis.

RESULTS

By variation of γ the effect of non-Gaussianity of vertical velocity fluctuations to the diffusion coefficient can be shown. On the other hand, by changing the skewness and the curtosis and calculating the corresponding γ values the influence of third and fourth moments to non-Gaussianity can be explained. Thereby, the relation of the two mode-parts to the statistics of the full vertical velocity fluctuations can be compared with results of concepts and measurements for the convective boundary layer (Hunt, Kaimal, Gaynor, 1988). Moreover, the influence of variations of the vertical profile of the skewness and it derivation is given.

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