NOTES AND CORRESPONDENCE

Comments on "Prediction of Wind Speed, Direction and Diffusivity under Neutral Conditions for Tall Stacks"

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Raghavan and Basu (1988) have reported on some results of a numerical model of the neutral PBL and diffusion in the same from tall stacks. Their model formulation and assumptions appear to be reasonable and not much different from similar TKE-closure models used by other investigators. However, there are some serious inconsistencies and errors in the author's results which may have resulted from the coarse resolution of their horizontal grid, viz., $\Delta x = 5$ km and $\Delta y = 1$ km.

According to the empirical Pasquill-Gifford dispersion curve for neutral stability, the expected values of the lateral dispersion parameter σ_y are about 0.07, 0.30, 0.55, 1.0 and 1.83 km at distances of 1, 5, 10, 20 and 40 km, respectively, from the source (Turner 1970). The authors' numerical model with a grid spacing (resolution) of 1 km in the lateral direction can hardly be expected to resolve this plume for short distances of 1 to 30 km where the maximum ground level concentration of pollutants from a tall stack is expected to occur. With such a coarse resolution, the spurious numerical diffusion is likely to dominate over any turbulent diffusion. It is no wonder that the authors find their results so insensitive to lateral diffusivity that even the total neglect of lateral diffusion ($K_y = 0$) does not seem to matter. Their conclusion that "the inclusion of cross-wind diffusion has only a negligible effect on ground level concentration" is totally unphysical and obviously wrong. One only needs to examine the differences in the well-known analytical solutions (corresponding to constant or height-dependent eddy diffusivities) of the advection–diffusion equation for an elevated point source and a cross-wind line source (no lateral diffusion) in order to realize the importance of lateral diffusion in the former. If only the authors had tested their numerical diffusion model against some standard analytical solutions, they would have realized the limitations of the coarse grid resolution and the resulting spurious numerical diffusion in their model. The authors' observation that "the vertical dispersion process is a faster process compared to the lateral dispersion process" is contradictory to their assumption that $K_y = 2K_z$ or $20K_z$. The spurious numerical diffusivity in their model appears to be much larger than their specified turbulent diffusivities. Consequently, their model-predicted ground level concentrations are much smaller than those predicted by the Gaussian model. This is not to say that the Gaussian model is better. But, a numerical model, even with complete physics and sophisticated closure assumptions, is no good if numerical errors tend to dominate the physical processes.

Another summary statement of the authors that "the location of maximum ground level concentration from the stack increases as H^4" is also grossly in error and not consistent with their Fig. 6. According to Fig. 6, $X_{max} \propto H^{2.2}$, which appears to be a more reasonable result when compared to other theoretical and experimental results.

There is also an apparent inconsistency in the authors' PBL model results. In their Table 1, the height h_{max}, where the maximum in eddy diffusivity occurs, decreases with increasing surface roughness. For a fixed geostrophic wind, one would expect u_* to increase with increasing roughness (the authors' Fig. 3 is also consistent with this). Since, h_{max} increases with increasing u_*, according to their Fig. 4, one would have expected the former also to increase with increasing roughness. In this connection, the authors' statement that "no numerical relationship has so far been established" for h_{max} is not correct. According to the similarity theory for the neutral PBL, normalized eddy diffusivity Kf/u_*^2 is expected to be a unique function of the normalized height fz/u_*, so that h_{max} must be a fixed proportion of u_*/f. The large-eddy simulation of the neutral PBL by Deardorff (1972) gave $h_{max} \approx 0.22\ u_*/f$, while the second-order closure model of Wyngaard et al. (1974) yielded $h_{max} \approx 0.24\ u_*/f$. In contrast, the proportionality coefficient in the authors linear regression relation for h_{max} is a factor of six too small. That

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is, their model considerably underpredicts the height of maximum diffusivity.

Finally, the authors have, probably, made too much of the height h_{max} of the maximum diffusivity in selecting an optimum stack height. In general, h_{max} may vary over a wide range, if one considers the expected range of geostrophic winds and stability in the PBL. The effective source height, including the plume rise due to momentum and buoyancy of the effluent, is also expected to be variable and may differ considerably from the stack height. Even if it were possible to match the effective source height to h_{max}, for a particular scenario, it does not necessarily follow that the long-range transport of pollutants could be minimized. Tall stacks are necessitated for bringing the maximum ground level concentration within the permissible (safe) limits. In the absence of surface deposition, long-range transport does not depend on the stack height. The material, whether from a surface source or from a tall stack gets eventually mixed through the whole PBL and transported long distances.

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