

Modeling Hazardous Gas Dispersion in Neutrally and Stably Stratified Atmospheric Boundary Layer Flows

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ABSTRACT

The objective of the present work is to propose a methodology to simulate hazardous gas dispersion in neutrally and stably stratified atmospheric boundary layer (ABL) flows. The profiles of velocity, temperature and turbulence quantities are set based on the stratification effect. Special emphasis is placed on the generation of a horizontally homogeneous turbulent boundary layer (HHTBL). FLUENT software is validated for simulating ABL flows by comparing the results obtained with available numerical data from the literature. The fully developed profiles of velocity, turbulent kinetic energy, turbulent dissipation rate and temperature are implemented as user defined functions in the commercial code FLUENT. The hazardous gas release is modeled using the convection diffusion equation. Four test cases from the classical Prairie Grass experiment are considered for validating the present approach. The predicted concentration of the SO_2 gas at various locations of the test field (50, 100, 200, 400 and 800 m) are in close agreement with the experimental data. The cases of neutral stratification compare quite well with the experimental data and there exist a slight discrepancy in the stably stratified cases. This mismatch can be attributed to measurement errors and the anisotropic nature of the ABL flows.

1. INTRODUCTION

Modeling the dispersion of hazardous pollutants and gases in an urban atmosphere has remained as a challenging area of research for the past few decades. With the advent of modern computers and the consistent increase of computational power, the task of computationally modeling the atmospheric boundary layers (ABL)/Planetary boundary layers (PBL) and the dispersion of hazardous gases have become totally viable. Modeling the earth's atmosphere is among the most difficult tasks that a computational fluid dynamics code has to handle. The velocity components, turbulent quantities and the temperature keeps changing rapidly and thereby makes the computational work a lot more horrendous. The simplest assumption that one would make while tackling such a problem is to consider the flow to be steady or quasi-steady in nature.

Modeling the transient behavior of the atmosphere is not far from imagination and is considered to be normal to perform studies for shorter durations to capture intricate flow features. The CFD analysis of ABL flows are performed by solving the Reynolds Averaged Navier-Stokes equations (RANS) or Large Eddy Simulations (LES). From a computational stand point, the RANS approach is more desirable owing to its robustness, simplicity and lower computational cost. With Reynolds averaging the number of unknowns increase in the form of Reynolds stresses and the closure of these set of equations turns out to be difficult. There exist a number of turbulence models to achieve closure of the RANS set of equations and the choice of the turbulence models for a particular application depends truly on past experience. The two equation turbulence models [1–4] are among the most widely used for predicting ABL flows. The k- ϵ model has been applied for modeling ABL flows and to simulate hazardous gas dispersion successfully in the past [5, 6]. The inherent disadvantage in a two equation model is that the anisotropy of ~~turbulent~~ cannot be ~~captured~~ using these models. The Reynolds Stress Model (RSM) or the Large Eddy Simulation (LES) can resolve the anisotropic effects but comes with a penalty of increased computation time.

turbulence

captured

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