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Large-eddy simulation of plume dispersion under various thermally stratified boundary layers

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There is a potential problem that hazardous and flammable materials are accidentally or intentionally released into the atmosphere. In such a situation, not only average levels but also instantaneous magnitudes of concentration should be accurately predicted. For understanding spatial distribution of plume concentration and characteristics of mean and fluctuating concentrations, a numerical modeling using Computational Fluid Dynamics is a useful tool. In particular, Large-Eddy Simulation (LES) is effective to capture unsteady behaviors of turbulent flows and plume dispersion. Recently, with the rapid development of computational technology, many researchers have developed LES-based CFD models for turbulent flows and plume dispersion. These models can provide detailed information about turbulence structures, mean and fluctuating concentrations.

However, these studies have focused on the characteristics of plume dispersion under the condition of neutrally stratified boundary layers. Heating and cooling within the boundary layer due to solar cycle during a day result in temperature differences, which introduce buoyancy forcing. The effects of buoyancy effects on the dispersion process of a plume are important factors in order to clarify the mechanism of atmospheric dispersion under a more realistic condition.

Therefore, we perform LESs of plume dispersion under stable and unstable boundary layers. In our model, the inflow turbulence is generated by the recycling method in a driver region and the target temperature profile is imposed at the exit of the driver region. Here, buoyancy effects modeled by Boussinesq approximation are incorporated into the downstream region of the driver region and numerical simulations of various thermally stratified boundary layer flows are performed. A tracer gas is emitted from a point source in a region where the boundary layers are fully developed and LESs of plume dispersion are carried out.

Our objective is to compare our LES results of turbulence structures, plume concentrations and plume spreads to wind tunnel experimental data and theoretical values, and investigate the basic performance of the model.