Advanced closure model for stably stratified turbulent boundary layer

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We propose a closure model for a stably stratified turbulent boundary layer over a flat plane, based on an isentropic model of the atmosphere which is used as a basic reference state. The definition of the potential temperature is revised and generalized for the cases of gases or liquids. The Navier-Stocks equation in the Boussinesq approximation is rederived using the generalized potential temperature. Currently we concentrated on the region of highly developed turbulence were viscous dissipation and molecular heat transfer are negligible and the only dimensionless parameter – "global" Richardson number, Ri, is important.

Suggested model consists of two exact equations for the mean velocity and temperature profiles and the full set of equations for components of the Reynolds-stress tensor, temperature-temperature correlations and cross velocity-temperature correlations. As a preliminary step we adopted “time-closure" in which all relevant triple correlation functions were expressed via corresponding pair-correlations and characteristic turbulent time, proportional to Ri-independent constants, (C_{uu}, $C_{u\theta}$ and $C_{\theta\theta}$) the turbulent velocity divided by the outer scale of turbulence. We found approximate (with $\sim 5\%$ accuracy) analytical solution of these equations for any level of stratification.

The advanced closure model expresses triple (cross)-correlators via pair (cross)-correlators and the Greens' functions in the framework of the Wylds' diagrammatic perturbation approach with Dyson line resummation for the Greens' functions and different-time pair correlations using approximation of bare interaction vertices, which are estimated within suggested "local algebraic approximation". As a result, we demonstrated that “time-closure constants" C_{uu}, $C_{u\theta}$ and $C_{\theta\theta}$ are indeed functions of Ri varying, fortunately, within finite limits when Ri goes from 0 to ∞. This means that for qualitative analysis one can use the time closure (with Ri-independent values of the “constants") and for semi-quantitative “predictions" – our analytical solution with phenomenologically corrected Ri-dependent “constants” C_{uu}, $C_{u\theta}$ and $C_{\theta\theta}$.