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Evaluating single column parametrizations of turbulent vertical diffusion for use in GCMs.

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In preparation for a new version of INM CM (Institute of Numerical Mathematics Climate Model) we conduct an evaluation of several $k - \varepsilon$ (either with standard equation or relaxation one), k, and zero order closures based on extensive set of DNS (Direct Numerical Simulation), LES (Large-Eddy Simulation), and laboratory experiments datasets as well as previously introduced benchmarks such as GABLS1 and GABLS2. Evaluation was carried out within a uniform numerical formulation. The role of stability functions and steady-state solutions on closure performance was evaluated. The extended ε equation with a relaxation to "equilibrium" term is also evaluated. The ''equilibrium" itself for horizontally homogeneous stably stratified flows is expressed using steady state turbulent kinetic energy budget equation and Monin-Obukhov Similarity Theory formulation of the velocity-gradient (see, (Zilitinkevich et al., 2019)). Moreover in this case the controversial constant defining the action of buoyancy on the dissipation rate in ε equation may be related to the ratio of von Karman constant and the critical Richardson flux number. In a more general form the new approach in deriving the ε equation leads to an additional relaxation term, which controls the adjustment of dissipation rate in non-stationary flows, and to our knowledge this adjustment mechanism may be missing in two-equation single column closures as used in large-scale models. As vertical resolution factors heavily in closure performance for stable stratification, an approach to solve closure on a dynamic nested vertical grid, in some sense making it a super parametrization, was implemented and evaluated.
Zilitinkevich, S., Druzhinin, O., Glazunov, A., Kadantsev, E., Mortikov, E., Repina, I., Troitskaya, Y. (2019). Dissipation rate of turbulent kinetic energy in stably stratified sheared flows. Atmospheric Chemistry and Physics, 19(4), 2489-2496.