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The Scaling Behaviour of a Turbulent Kinetic Energy Closure Model for Stably Stratified Conditions

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Turbulent kinetic energy (TKE) closure is more and more applied in research models, but most large scale operational models still apply first-order closure. One of the reasons is, that uncertainties exist in the scaling behaviour of TKE models. It is also questioned whether this behaviour can be controlled.

We investigate the scaling behaviour of a TKE closure model for stably stratified conditions. In TKE models, the eddy-diffusivity is a function of TKE and a mixing length. For stable stratification, we take the mixing length proportional to the ratio of the square root of the TKE and the local Brunt-Väisälä frequency, which is a commonly applied formulation. We analyze how the scaling behaviour depends on model parameters and whether it is robust. From the model equations, expressions are derived for the stable limit behaviour of the flux-gradient relations and other scaling quantities. It turns out that the scaling behaviour depends on only a few model parameters and that the results follow local scaling theory. We also investigate solutions for the case in which the eddy-diffusivity for momentum is expressed as a function of the Richardson number (i.e. an increasing turbulent Prandtl number with stability).

These analytical results are illustrated by four model runs with different mixing characteristics: we varied the mixing efficiencies of momentum and heat and the dependency of the Prandtl number on stability. The model output is compared to the analytical findings. It seems that for certain parameter combinations the model cannot generate a steady-state solution. At the same time, its scaling behaviour becomes unrealistic. However, in this case the corresponding stability functions are comparable with the ‘long tail’ stability functions which are apparently needed by large-scale models.